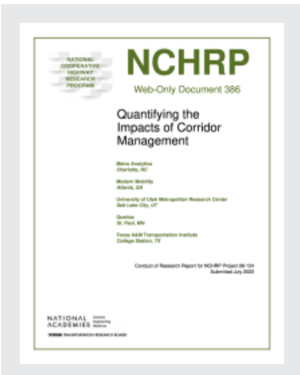

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Quantifying the Impacts of Corridor Management

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Conduct of Research Report for NCHRP Project 08-124
Submitted July 2022

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed, and implementable research is the most effective way to solve many problems facing state departments of transportation (DOTs) administrators and engineers. Often, highway problems are of local or regional interest and can best be studied by state DOTs individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation results in increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

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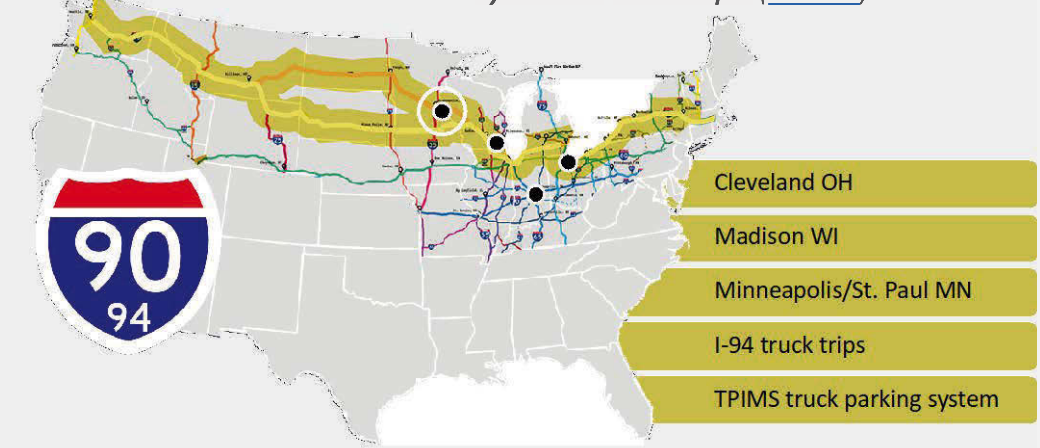
Introduction

Corridors Bind the Nation Together. It Matters How We Manage Them.

Transportation Corridors are defined by the infrastructure, services, and relationships connecting places. A corridor can be a national resource connecting large cities, a regional passage connecting a state's trade centers, or local pathways connecting through a city or town. This playbook is for professionals and groups seeking to have a quantifiable impact on how corridors perform for states, communities, neighborhoods, businesses, and people. Plays are offered for understanding how specific corridor management efforts should be defined and approached, what it means to manage a corridor, and how to manage different types of corridors for intended impacts.

Corridors Are Interactive Systems: I-90 Example (APP 3.4)



What is the I-90/94 Corridor? I-90 is often understood as an expansive interstate highway joining the nation from Boston to Seattle. The map above demonstrates I-90 as part of a larger I-90/94 System.

More than a Highway: The people communities in the I-90/94 system experience it as much more than a connection across the United States. In Cleveland, I-90 represents an often-difficult passage for trucks in winter snow conditions, where advanced weather technologies can manage speeds, routing, and demand. In Madison, Wisconsin, I-90 represents a lifeline of trade and commuting to 27 cities and towns in the metropolitan area requiring a balance of access for local deliveries and workers and a viable lifeline to national commerce. In Minneapolis, I-94 (part of the larger I-90 system) represents a harsh legacy of physically dividing the Rondo neighborhood in St. Paul and an opportunity to heal past injustices for a new and more equitable future. From Michigan through Minnesota, I-94 represents a complex market for truck parking locations, with new parking demand management technologies enabling commerce to serve communities throughout these states enabling carriers to better serve markets while safely complying with hours-of-service requirements.

Corridor management is about understanding what a corridor does, whom it serves, and how it can be improved. When managing a corridor for impact it is important to ask: who are the players in corridor management? What are their roles? And what is the intended impact of any given corridor management effort or coalition?

What the Playbook is About

Topics the Playbook Addresses

Defining the Corridor Manager: Understanding Corridor Management Players, Positions, and Roles

A key to effectively managing a corridor for impact is knowing the types of players involved and their roles. If a state agency attempts to manage a corridor only to achieve statewide performance targets based on its authority and ownership of the infrastructure, it may miss out on key opportunities to create value in local economies or support a local tax base. If a stakeholder coalition attempts to manage a local main street solely to enhance community quality of life it may encounter unintended impacts related to safety or mobility challenges or have effects on other communities who rely on reliable passage through the area. Success requires knowing who the players are, their unique opportunities for impact, and how to engage them. For this reason, practical plays are needed to identify the players in a corridor strategy, and adeptly manage their unique impact potential.

Getting Players on the Team: Building Durable Coalitions and Partnerships

Coalitions and partnerships have long been understood as essential to corridor management. NCHRP Synthesis 337 (2004) describes how memoranda of understanding, joint powers agreements, and other arrangements can formalize a corridor coalition.[1] However, a durable coalition requires more than simply an agreement to participate in a corridor. Successful corridor managers follow programmatic steps to identifying coalition partners over time, keeping a coalition current, and tracking corridor management outcomes to demonstrate intended payoffs for coalition partners. Practical plays on building and sustaining durable coalitions focused on performance is a recommended feature for impact-based corridor management.

Setting Up the Play Field: Understanding Corridor Typologies, Assets and Liabilities

Corridors are often defined by their geography, stakeholders, assets, and liabilities. However, a corridor's assets go far beyond simply available infrastructure. Liabilities may go far beyond engineering deficiencies. Successful corridor management entails consideration of high-value locations, economic assets like natural resources, universities, international gateways, or concentrations of knowledge workers. An inventory entails considering liabilities such as poverty, political instability, or a dearth of funding availability. It is also important for corridor managers to understand corridor liabilities and pain points as well as missing assets. What should be part of this corridor portfolio that is currently missing? A practical play for assessing corridor assets and liabilities both for the present and future is integral to effective management.

[1] Kristine M. Williams. *NCHRP Synthesis 337: Cooperative Agreements for Corridor Management* (Washington D.C.: Transportation Research Board of the National Academies, 2004), https://www.nap.edu/read/23332/chapter/1#vi.

Playing to Win: Corridor Management Strategies

The strategies both for managing corridors and demonstrating the impact of corridor management grow from knowing the corridor's players, assets, liabilities, and intended impacts. Successful corridor management pinpoints strategies based on a holistic understanding of who the current and intended users are, the desired impacts of the management effort, and how those factors may change over time. A play on selecting management strategies with a firm grasp of how the impact is envisioned, measured, and evaluated is a key feature of effective management.

Keeping Score: Benchmarks, methods, and techniques

Historically, corridor management has often centered around a singular "corridor study" undertaken to develop objectives and strategies and updated periodically. However, what are managers to do if the world changes before a corridor study is updated? What if the study is never updated? Are there ways for corridor managers to track how the world changes around them and adjust their coalitions and management strategies in real-time? A play for practical uses of benchmarking and techniques for navigating a changing corridor environment is a vital feature of a corridor management strategy.

It's about adapting for the future: Sustaining management regime/effort

Can a corridor management regime be "future-proof"? Are there ways to identify and track if a corridor has a "personality type" and how a corridor's economic, demographic, or physical "personality" changes over time? How do emerging opportunities in areas such as big-data or machine learning present opportunities for corridor management regimes to function as living-learning systems? A play for future-proofing the practice of corridor management, establishing a learning-corridor research roadmap can set the groundwork for a new future in corridor management.

How to Use the Plays

The plays that follow provide helpful tips and guiding principles, not strict rules. Like any list of strategies, they are not all-inclusive, nor will they all be relevant to a location's specific needs. While some plays may ideally be implemented in sequence, they do not need to be implemented in a particular order and should add value to any corridor management effort whether individually or taken together. The knowledge and expertise they provide can be used in part or as a whole, in any combination, and in any order. The Playbook represents many experiences, some shared from multiple locations across the country.

When using this playbook, feel free to change up the plays to suit local needs. The research offers best practice techniques and innovative methods for quantifying the impact of corridor management and using state-of-the-art measures and techniques observed in the research. However, it is not intended to address every problem in process of corridor management. It is offered to facilitate a new generation of corridor management efforts that address emerging issues of equity, resilience, and an increasingly collaborative corridor management environment. The hope is that this playbook will be a starting point for more innovative practices and tools to be developed from these basic plays.

As the plays are executed and new ones are developed, practitioners are encouraged to share their success through collaboration with the American Association of State Highway Transportation Officials (AASHTO), the Transportation Research Board (TRB), and other associations. The final play on future-proofing and new research is hoped both to introduce innovative/exploratory elements with which corridor managers may experiment, or subject areas for new research to complement this current playbook.

The eight plays are listed below and summarized in Figure 1 on the next page.

PLAY 1 | Define the corridor and its impact

PLAY 2 | Take inventory of the corridor

PLAY 3 | Build durable coalitions and process

PLAY 4 | Build a spatial analysis environment

PLAY 5 | Select strategies and supporting methods/data

PLAY 6 | Balance competing uses and sources of value

PLAY 7 | Evaluate effectiveness of corridor strategies

PLAY 8 | Futureproofing a corridor

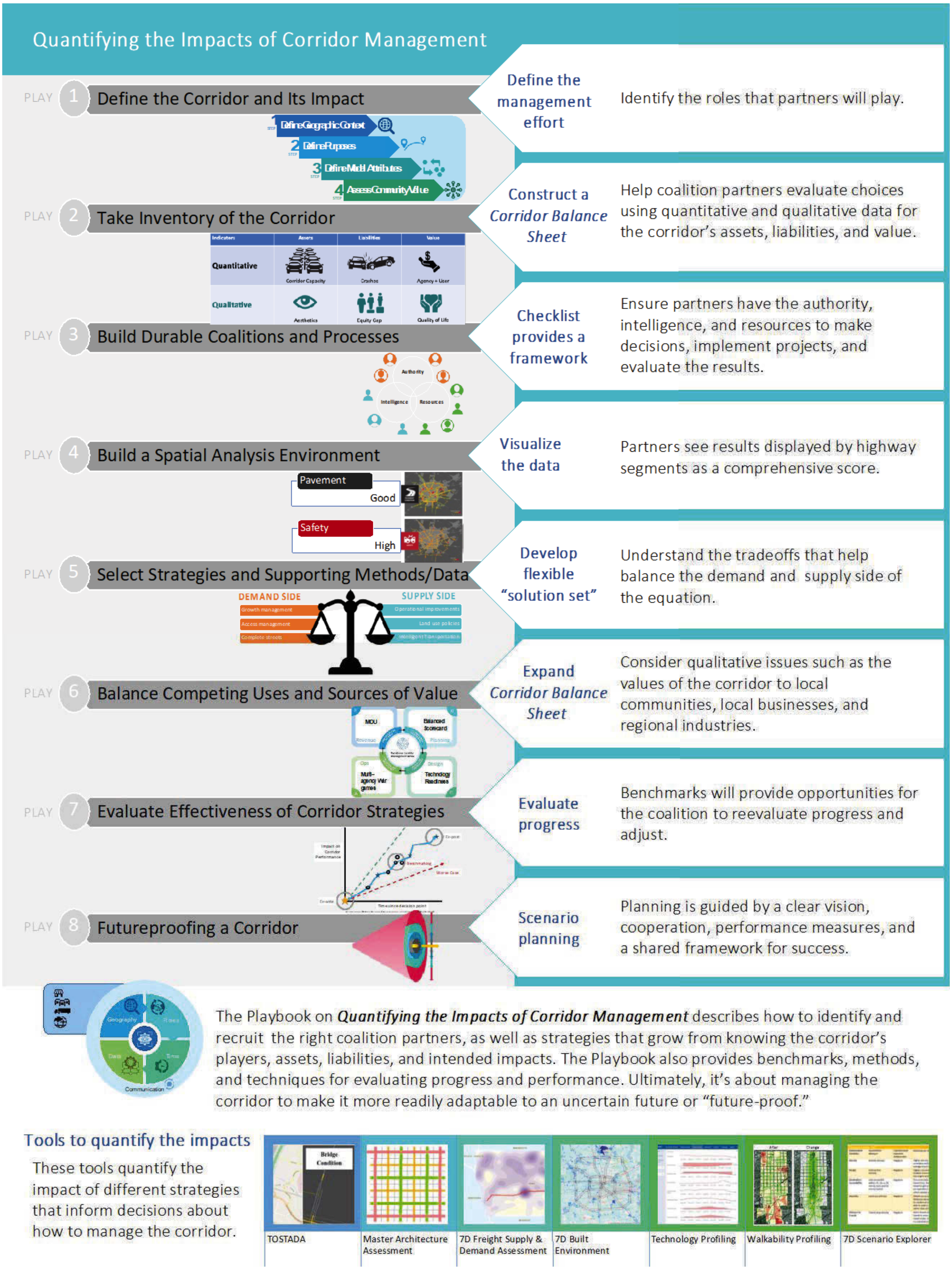


Figure 1 Summary of Quantifying the Impacts of Corridor Management Playbook

NCHRP Objectives

The objective of this research is (1) to produce a framework for measuring the impacts of corridor management, demonstrating applicable strategies and techniques; and (2) to develop guidelines for how to implement that framework. This framework should focus on multi-jurisdictional corridor-wide transportation and land-use planning that affects community and economic vitality. It should reflect a desire to maximize public value by implementing programs for effective infrastructure improvements and investments at a corridor level. In addition, it should provide guidance for state DOTs, regional, and local transportation and land-use planning agencies, working together with both public and private stakeholders, to coordinate development planning and infrastructure investment in multi-modal passenger and freight transportation networks. The framework should include, at a minimum, the following:

1. A working definition of what a corridor is, what is meant by corridor management, and a description of how that definition has evolved
2. A delineation of the primary components of a corridor management program and how those components address measuring public value and sustainability
3. A description and review of current experience, including existing tools and techniques used to measure impacts and implement a corridor management program in support of various planning and management objectives
4. A matrix or other organizing technique that can be used to classify the variety of corridors as a basis for the framework
5. Recommendations for models and/or strategic approaches to measuring impacts (quantitatively and qualitatively) and integrating current practices with potential changes that can occur, taking into account risk and uncertainty in long-term planning and forecasting methods.

PLAY 1 Define the Corridor and Its Impacts

What is a corridor? What does it mean to manage and operate a corridor informed by an understanding of its actual or desired impact? Answering these questions requires (1) defining the scope of any given corridor management effort, (2) getting oriented to where a corridor management effort stands in the larger network of corridor systems, and (3) understanding how the current corridor profile relates to a desired or potential profile in a changing world.

Define a Corridor as an End-to-End Connection: Connecting Resources, Markets, and People

When defining a corridor management effort, it is helpful to define the corridor in terms of end-to-end connections, instead of facilities. It can often be helpful to identify resources and markets to be connected and find corridor termini representing where the underlying markets are located. In this way, a corridor may not have only two termini but maybe a fork, or a system connecting multiple nodes. One of the first state DOT corridor programs (in Minnesota) defined an inter-regional corridor system comprised of different tiers of trade centers, defining different tiers of "corridors" as to how different tiers of trade centers were connected.[2] Figure 2 illustrates how Minnesota defined inter-regional corridors in terms of a hierarchy of trade centers in its ground-breaking 1999 Statewide Interregional Corridor study. The trade-center approach taken in Minnesota, and the establishment of corridors of significance based on regional trade connections became the pre-cursor to other statewide corridor programs in Iowa, Michigan, North Carolina, and other states in the 21st century.[3]

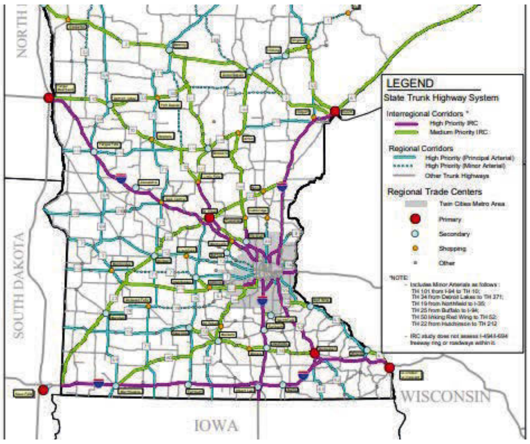


Figure 2: Minnesota's Inter-Regional Corridor System Defined by Trade Centers and Different Tiers of Corridors
(Source Mn/DOT InterRegional Corridor Study 1999)

It is helpful to understand examples of how corridors and corridor systems have been defined (APP 2.4) when defining a corridor management effort. Using a set of "ends" or "termini" as a definition approach enables corridor managers to begin with a holistic view of what comprises a corridor. For example, the Alameda Corridor (APP 3.7.7), by defining termini at the ports of Los Angeles and Long Beach, respectively opened the overall corridor management effort to considering a wide range of port, rail, air, and highway facilities as well as vital economic and community assets in its solution sets. The process of defining end-to-end connections before

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[2] SRF Consulting Group, Inc. "Statewide Interregional Corridor Study" (Minnesota Department of Transportation, 1999), http://www.dot.state.mn.us/planning/program/pdf/IRC_Technical_Report.pdf.

[3] Iowa Department of Transportation. "Iowa in Motion – Iowa State Corridor Plan" (2013), http://publications.iowa.gov/18836/1/IADOT_Interstate_Corridor_Plan_2013.pdf; Michigan Department of Transportation, "Corridors of Highest Significance," 2018, http://www.michiganmobility.org/learn/corridors_highest_significance.aspx; North Carolina Department of Transportation, "Strategic Transportation Corridors (STC)," Connect NCDOT Business Partner Resources, accessed Oct. 21, 2021, https://connect.ncdot.gov/projects/planning/Pages/NCTransportationNetwork.aspx.

naming infrastructure assets, specific destinations, or pain points enables corridor managers to consider the wide range of potential impacts and players in context. Successful corridor management efforts have defined corridors in terms of connections between resources and markets (APP 2.4.1), whether for labor, freight, recreation, or other activities.

Define the Scope and Role of a Corridor in Context

Because corridors are part of much larger networks, a corridor management effort will only be managing one part of the corridor's identity. When defining the scope of a corridor management effort, it is important to first consider the larger system of which your corridor is a part. Understanding corridors as nested systems (APP 3.3) can be a helpful way of identifying other agencies and groups that may be managing the same corridor, but at a different level or in a different context.

How is a corridor "Nested"?

- ✓ *Identify communities/stakeholders that are within a same-day travel radius of the corridor's termini.*
- ✓ *Check with DOT, Municipalities to see if other coalitions or management efforts exist*
- ✓ *Identify user-groups who may use the corridor for (1) commerce, (2) recreation, (3) exercise, (4) business location or (5) other uses.*

For example, if managing a downtown Main Street, it is important to understand that Main Street could also be a principal arterial, and a tributary connecting the entire community to a larger interstate or freeway system. Likewise, if managing an interstate highway between three cities, it is important to understand that within each city the highway facility could be (1) a barrier between neighborhoods, (2) a source of noise or air quality concern to local communities, (3) a lifeline to households and businesses reliant on its access to supply businesses or commuting. The case example of US 15/501 in North Carolina (APP 3.5.9) illustrates a tributary corridor that connects two communities, and even neighborhood destinations across multiple modes, while also providing vital tributary access to the I-85/95 system. It also plays a critical role in the overall development of Durham and Chapel Hill, NC. When defining a corridor impact area and scoping the management effort, it is helpful to reconsider the definition within the context of Play 3: Build Durable Coalitions and Processes on building and sustaining coalitions. An aspect of successful coalitions is their ability to (1) iteratively update and re-define their area of influence and (2) forge lasting relationships with other coalitions managing related parts of the larger corridor ecosystem, comprised of different organizations and entities responsible for components of corridor markets and infrastructure.[4]

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[4] University of California at Berkeley, "The Connected Coridors Ecosystem," *Connected Corridors Program* (2021), https://connected-corridors.berkeley.edu/planning-system/selecting-corridor/engaging-stakeholders/connected-corridors-ecosystem.

Get Oriented: Select Characteristics to Define the Corridor Management Regime

Because corridors are complex, it can be difficult to understand which performance measures, data sources, impact methods, or stakeholders are relevant for managing impact. There is a wide range of methodologies, performance indicators, and data sources that can inform a corridor management process if managers have a clear understanding of corridor management objectives (APP 2.7, Table 3). A principal challenge of defining a corridor management effort entails establishing corridor objectives specific enough to suggest a manageable set of performance indicators. Figure 3 below demonstrates an overarching process for managing corridors, in which the umbrella represents a starting point for recognizing where the corridor fits into the overall larger system of transportation markets, considering both the infrastructure (supply) as well as changing market (demand) aspects of the context. The red boxes suggest steps for establishing a management regime, such that specific tools, data, and methods (shown in the green boxes) can be pinpointed best suited to the expectations and motivations of corridor management partners. Detailed guidance on each of the programmatic steps of corridor management, and how to best use the entire suite of resources from this Playbook in a corridor program are given in Appendix 5.1.

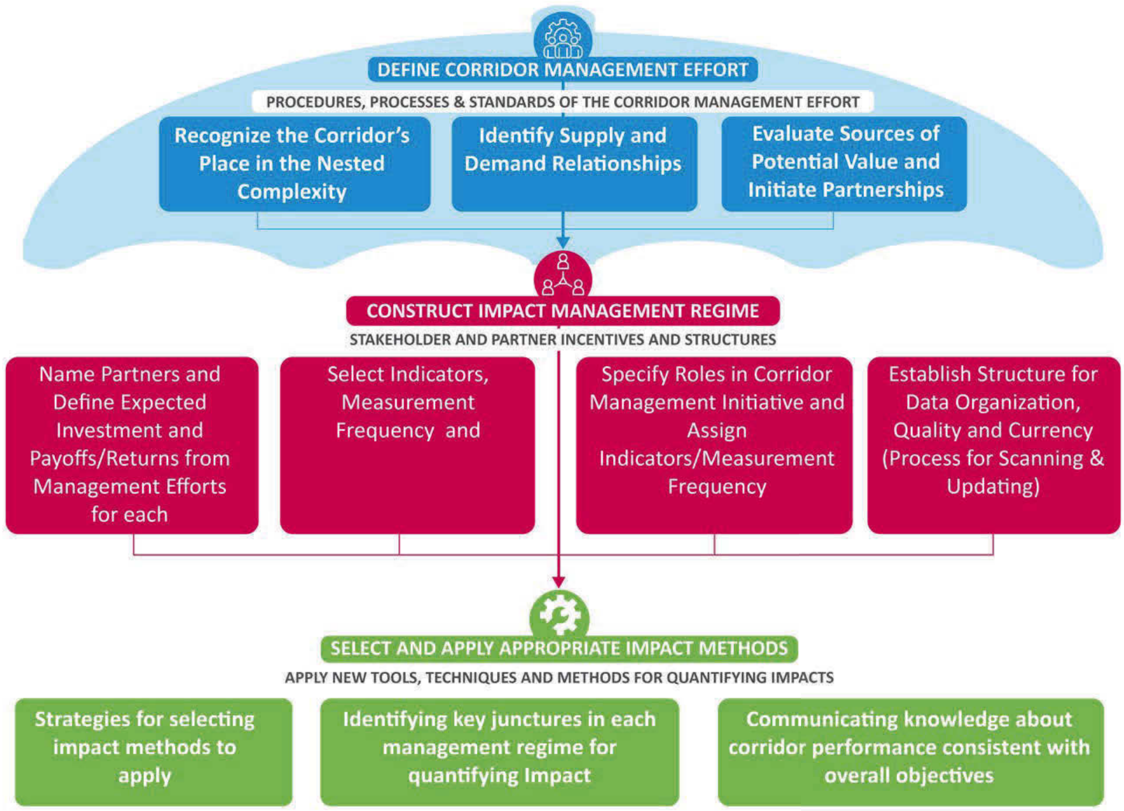

Figure 3: Corridor Management Framework from Defining Corridors through Selecting Indicators

For this reason, it can be helpful to begin with some basic facts about a corridor in the scoping and definition process. For example, simply by considering factors such as (1) the geographic context and area-types connected by a corridor, (2) the types of trips, commodities, or freight movements of interest, (3) available (or desired) modes of transportation, and (4) characteristics of affected communities interfacing with the corridor; it is possible to significantly narrow down the menu of relevant data, methods, performance indicators and stakeholders for defining a corridor impact management regime. Figure 4 below offers a step-wise process for "orienting" a corridor to its context in such a way that can enable managers to select which data, methods, tools, and partners will best serve a corridor management initiative.

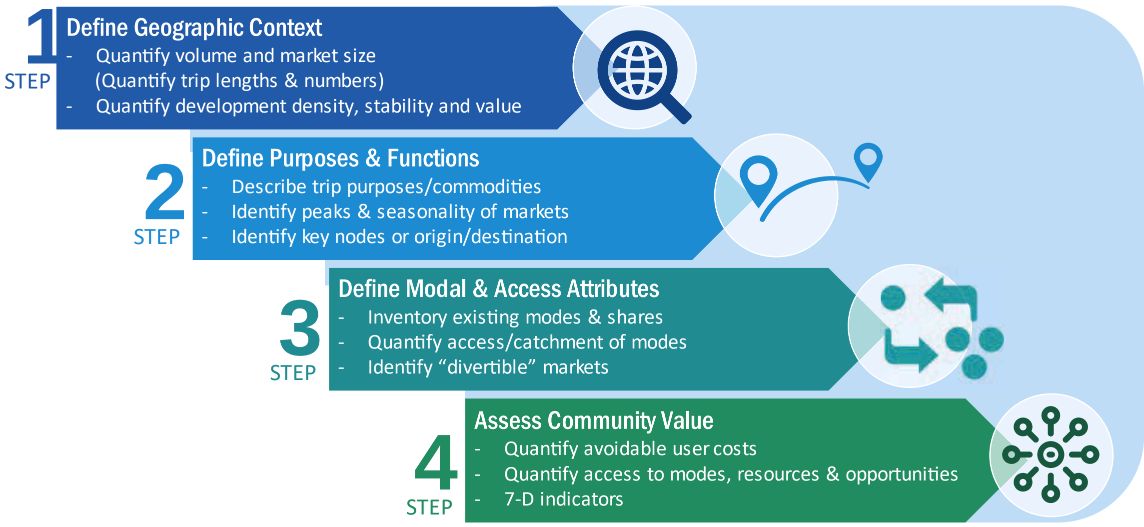

Figure 4: StepWise Corridor Orientation Method

To facilitate this process, corridor managers are encouraged to use the *Corridor Orientation Tool* (APP 7 and APP 8), which uses corridor typologies (APP 6.2) to walk through each step of this process, pinpointing specific classes of stakeholders, performance indicators, and analysis methods for any given corridor effort based on the starting context of the corridor management effort. *The Corridor Orientation Tool* can be used iteratively, first when defining the corridor management effort, and in later stages, as needs change or additional stakeholders join a coalition. For this reason, the uses of the tool and its approach are further referenced in Play 5: Select Strategies and Supporting Methods/Data.

Define the Corridor in Aspirational Terms

It is important not to limit the definition of a corridor to its existing needs and characteristics. When considering a corridor's typology, it is helpful to apply the steps and methods of this play not only in terms of existing characteristics, but future desired or needed characteristics. For example, even if a corridor today does not include multiple passenger or freight modes or does not traverse dense suburban or urban areas it may be wise to include these characteristics in the corridor definition when stakeholders view such changes on the horizon. Managers following the steps shown in Figure 4 and described in Appendix 6.2 and applying the *Corridor Orientation Tool*, may take a holistic approach, basing their corridor profile on the full range of possible corridor attributes motivating the management effort. Such a process will bring in a broader range of stakeholders, data, indicators, and methods, but will also make for a more robust process. Play 3: Build Durable Coalitions and Processes and Play 8: Futureproofing a Corridor further address durable coalitions, and "future-proofing" corridors through holistic scenario planning.

Defining corridors in aspirational terms is of particular importance when land development is transforming the area surrounding a corridor. Understanding how changes in development density, access density, and available right-of-way affect future performance needs is vital to defining a corridor. Appendix 2.5 provides discussion for pinpointing risks associated with rapidly urbanizing corridors, where defining corridors based on today's attributes can pose significant performance risks in the long term. Appendix 5.4 and Appendix 5.8 offer a specific methodology for diagnosing changes in corridor build-out and quantifying the adequacy of a corridor's core infrastructure and surrounding support-network potential for rapid and eventual build-out. The use of these and other methods for quantifying impacts are further explored in Play 7: Evaluate the Effectiveness of Corridor Strategies.

PLAY 2 Take Inventory of the Corridor

Corridors are often defined by their geography, stakeholders, assets, and liabilities. However, a corridor's assets go far beyond available right-of-way and the improvements to the land infrastructure (pavements and structures). Likewise, liabilities may go beyond physical or functional obsolescence. Successful corridor management includes consideration of high-value locations and economic assets (natural resources, universities, international gateways, or concentrations of skilled workers). An inventory includes considering liabilities such as poverty, political instability, or scarce funding availability (both public and private equity investments). It is also important for corridor managers to understand corridor liabilities and pain points and missing assets. What should be part of the corridor portfolio that is currently missing? A practical play for assessing corridor assets and liabilities both for the present and future is integral to effective management. The literature search conducted for this project identifies work on corridor infrastructure; however, these attributes include items such as route length, area coverage, and infrastructure density, and work on how to conduct a features inventory of transportation and area land-uses is absent (APP 1, Table 1). The land-use elements in Appendix 1, Table 2 include transportation/land-use integration policy and change prediction. While specific guidance on establishing existing and desired corridor conditions does not appear, there is information on the integration of land-use and transportation planning and examination of land-use changes catalyzed by transportation improvements.

Define the Corridor's Market Area and Planning Time Horizon

Defining a Market Area: To inventory corridor assets and liabilities, it is essential to define the universe of space, infrastructure, and economic activity that are considered to be part of the corridor. Defining the market or influence area of a corridor is as much a qualitative as a quantitative process that defies a purely rational approach. The literature is silent on this topic. In the example of the US 54-400 corridor in Andover, Kansas, the definition of the influence area became a political process.[5] Andover, Kansas prides itself upon being a lower-density, bedroom community to the Wichita, Kansas MSA. It's small-town providing living less than 30 minutes from work. The notion of increasing traffic accommodation and development density was anathema. The definition of the corridor influence area was re-framed as a narrow corridor (1,200' total width) with the connected transportation network to support triple the usual development density. This narrow, dense, mixed-use corridor provides Andover the economic engine to support the lower-density bedroom-community identity elsewhere. The selection of the influence area is essential to the success of a corridor management effort, as the influence area determines the universe of assets that can create value in a corridor as well as the universe of performance liabilities that may be addressed through corridor improvement actions. Based on the full body of case research and literature consulted, Table 1 below summarizes some key considerations for selecting a corridor influence area.

[5] Parsons Brinckerhoff, Inc, "City of Andover US 54/400 Corridor Study" (December 2011), https://www.andoverks.com/DocumentCenter/View/1294/Andover-US-54-Corridor-Plan-Report.

Table 1: Guidelines for Setting Corridor Market Area Boundaries

Defining Considerations	Effect on Corridor Influence Area
Criterion #1 Proximity: Drive time, truck delivery time, or mileage from/to corridor termini or core infrastructure elements. (Drive time or mileage standard buffer or margin)	**Minimum:** Influence area should encapsulate at least a 30-minute commuting radius of core infrastructure assets, and a 180-minute freight delivery radius (or same-day round-trip radius) of key freight assets or international gateways. **Maximum:** Influence area should not extend beyond proximity within which freight or passenger trips can reasonably be expected to utilize the corridor.
Criterion #2 Jurisdictional Boundaries: Boundaries of cities, states, counties, or other governmental entities that may be valuable as coalition partners, or may have authority to support corridor management efforts.	**Maximum:** Boundary areas should include enough jurisdictions can draw and support more robust coalitions and resources. **Minimum:** However, unnecessary inclusion of problematic or uncooperative jurisdictions can make the process unduly complicated. Boundaries should include only jurisdictions reasonably expected to (1) experience impact and (2) offer input or resources to the management effort.
Criterion # 3 Policy Sensitivity: Limitation of market area to areas that can reasonably be expected to be responsive to corridor improvement strategies.	**Maximum:** Boundary areas should be small enough that effective management tactics can reasonably show a % change in key indicators such as congested VMT, population, or business within commuting or delivery radius. **Minimum:** They should at least be large enough to capture the full extent of accessibility effects.
Criterion #4 Political Constituencies: Boundaries that align with political districts, stakeholder groups, or other entities which may have a particular interest in the corridor management process.	**Subject to other Criteria:** Boundary areas should not be artificially constructed in ways that contradict criteria 1, 2, and 3 above solely to address political constituencies. However, areas should be inclusive of interested political districts or entities when the other criteria are met.

Defining a Time Horizon: In addition to selecting an appropriate physical market influence area for a corridor, managers should select an appropriate time horizon in which to consider a corridor's assets and liabilities. Because highway and bridge infrastructure can have a life of 25-50 or more years, it is advisable to choose a planning horizon long enough to account for a stream of benefits that may result from corridor management actions. For example, if a corridor strategy may involve a $50 million bridge replacement for a bridge with a 50-year life, then it is prudent to select a planning horizon that will capture not only the $50 million outlay during the construction period but also the long-term life which the bridge is intended to serve.

Construct a Corridor Balance Sheet

A corridor's "Balance Sheet" can be understood as a summary of its assets and liabilities as an economic resource within the corridor market area over the selected time horizon. In business terms, corridor management is a way to increase a corridor's overall value by investing to reduce its liabilities while enhancing its assets. Unlike corporate balance sheets, a corridor balance sheet may include both tangible (quantifiable) assets and liabilities as well as intangible (soft) considerations. The objective of inventorying a corridor in balance sheet terms is not to engage in an accounting exercise so much as to recognize (1) which aspects of a corridor can be understood as assets, and which aspects are liabilities, (2) consider ways that a corridor's economic value or equity can be enhanced through management strategies, and (3) revisit the balance sheet over time to assess if there is a "Bottom Line" improvement in corridor value through the management effort.

This inventory can be enhanced through the lens of the 7-D's developed in this project that combines both quantitative and qualitative data into a more comprehensive evaluation of the corridor than is historically typical (APP 1, Table 3). Table 2: Account for Sources of Value below is an example of how a corridor balance sheet can be developed and revisited/updated over time to support both the establishment of objectives as well as the evaluation of management strategies.

Table 2: Account for Sources of Value

Types of Indicators	**Assets** ***Sources of Benefit in a Corridor System*** *(Reported as Annual or Current Year Value)*	**Liabilities** ***Sources of Avoidable Cost*** *(Reported as Discounted Value over the Time Horizon of the Corridor)*	**Corridor Value** ***Overall Assessment of Corridor Value*** *[Reported as net value (Assets-Liabilities) or as ratio (Assets/Liabilities)]*
Quantifiable Economic Indicators	• Residual Asset Value of Highway & Bridge Infrastructure (based on lane-miles, # bridges, and remaining service life) • Value of Transit and Inter-Modal Freight Infrastructure • Assessed Value of Real Property within Market Area • Assessed Value of Technology Assets • Earning Power of Workforce Accessible in 30-minute commute • Business Output of Establishments within 3-hour same-day delivery radius	• Personal Travel Time spent by cars and trucks ($ per person-hour) • Freight Travel Time consumed by goods in transit on the corridor • Reliability Time/Buffer Time spent by establishments due to congestion/bottlenecks. • Vehicle Operating Costs incurred for cars and trucks • Crash costs incurred due to safety incidents • Emissions costs incurred due to utilization • Annual cost to preserve highway and bridge assets • Annual cost to preserve, operate and maintain transit • Annual costs to preserve, operate, and maintain freight multimodal infrastructure	• Assessment of overall value offered by corridor. May be expressed in terms of a ratio demonstrating overall economic activity supported per dollar of transportation user or agency costs. Some examples of corridor balance sheet ratios include: • Public Agency Cost/$ of business output supported • Private User Cost/$ of business output supported • Total Cost (Agency + User)/$ of business output supported.
Intangible Indicators	• Aesthetic Amenities (expressed on scale of 1-5) • Endangered Habitats Sustained in Corridor (expressed on scale 1-5)	• Aesthetic liabilities of Corridor (expressed on scale of 1-5) • Equity Gap on the Corridor (expressed on a scale of 1-5)	• Enumerate specific features or qualities of the corridor which account for its intangible value, describing each and how it is sensitive to corridor strategies.

Accounting for Assets: Sources of value include publicly and privately held land, public infrastructure, and private equity investments as well as intangible factors such as aesthetic amenities or endangered habitats. Tangible asset values for transportation infrastructure can be quantified in terms of replacement value and remaining service life using accepted transportation asset management techniques as summarized in both the USDOT/FHWA Life Cycle Costs Primer as well as NCHRP 23-06.[6] Land values can be provided by local municipal tax assessor parcel databases. Household earning power (in terms of wage income) and business output can be ascertained from US Census data, data from the US Bureau of Economic Analysis, or privately syndicated services such as Moody's Analytics, IMPLAN, or Regional Economic Impact Models, Inc. Assets are reported as a snapshot of everything the corridor economy and infrastructure does (or is worth) projected at the end of the planning time horizon.

Accounting for Liabilities: Corridor liabilities include the societal costs of maintaining and using the transportation on the corridor over the entire planning time horizon. Liabilities can be understood in three categories: (1) societal costs to households and businesses of using the corridor or affected third parties (such as those affected by safety or environmental effects) (2) agency costs of maintaining the corridors' infrastructure – including hard infrastructure preservation as well as operating things like transit lines, ports, or freight terminals and (3) intangible costs such as equity gaps, aesthetic impositions, or other qualitative measures. User costs can generally be quantified using the values such as those provided in the *AASHTO Red Book User Benefit Analysis for Highways TCRP 78: Estimating the Benefits and Costs of Public Transit Projects – A Guidebook for Practitioners*, and the *USDOT/FHWA Economic Analysis Primer.* [7]

Accounting for Corridor Value: The inventory of assets and liabilities equips corridor managers with multiple ways to represent balanced corridor value. Because a corridor's value is a function of factors that may be beyond the control of corridor managers it can be helpful to use ratios. For example, considering the wage income/dollars spent on transit, or business output in key manufacturing sectors/dollars spent on freight infrastructure may be relevant metrics. Corridor managers and supporting coalitions can choose from several different balance-sheet values depending on how the corridor has been defined (as in Play 1: Define the Corridor and Its Impact) and the coalition partners (as in Play 3: Build Durable Coalitions and Processes). If corridor managers wish to fully integrate the tangible and intangible assets and liabilities into a singular index of corridor value, multi-criteria methods can be applied to assets and liabilities in the balance sheet with the methodology.[8]

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[6] US Department of Transportation Federal Highway Administration Office of Asset Management, *Life-Cycle Cost Analysis Primer*, (August, 2002), http://site.iugaza.edu.ps/nour/wp-content/uploads/7-DOT-LCCA-Primer.pdf; Transportation Research Board, "NCHRP 23-06: A Guide to Computation and Use of System Level Valuation of Transportation Assets," (2021), http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4787.

[7] American Association of State Highway and Transportation Officials, *User and Non-User Benefit Analysis for Highways* (Washington, DC: AASHTO, 2010); Transportation Research Board, *TCRP Report 78: Estimating the Benefits and Costs of Public Transit Projects - A Guidebook for Practioners* (Washington, DC: 2002), https://onlinepubs.trb.org/onlinepubs/tcrp/tcrp78/guidebook/tcrp78.pdf; US Department of Transportation Federal Highway Administration Office of Asset Management, "Asset Management (Economic Analysis Primer)," (March 2021), https://www.fhwa.dot.gov/asset/.

[8] Tsamboulas, Dimitrios A., George Yiotis, and George Mikroudis, "A Method for Multi-criteria Analysis in Transporation Infrastructure Investments," *International Journal of Transport Economics / Rivista Internazionale Di Economia Dei Trasporti* 34, no. 1 (2007): 113–31, http://www.jstor.org/stable/42747790.

Use the Corridor Balance Sheet to Evaluate Choices

The corridor balance sheet itself provides a mechanism for managers and coalition partners to holistically (1) hold a common understanding of drivers of corridor value and (2) pinpoint the features which may enhance or dilute the value over time. Once the corridor balance sheet is in place, managers can consider implications of ex-ante, ex-post, and benchmarking evaluations to identify issues, evaluate scenarios and make decisions over time (as described in Play 1: Define the Corridor and Its Impact). For example, using a balance sheet of the type shown in Table 1, managers may focus on strategies to reduce specific avoidable costs, add economic or infrastructure assets, or some combination of the two. Managers may then use predictive models to 1) assess pathways to enhance corridor value, 2) benchmark incremental changes in value, and 3) reflect on changes in corridor value over the life of the management effort. It may be advisable for corridor management charters or strategy documents to include a recurring balance-sheet-evaluation process at annual or bi-annual intervals to keep the management perspective current.

Stratified Return on Investment: Organizing a corridor balance sheet reveals that the sources of value on a corridor may accrue to different parties. For example, all of the costs of performance liabilities do not fall equally across stakeholders, nor does the value of all assets equally benefit all stakeholders. The balance sheet allows managers and coalition partners to transparently identify the expected payoffs of corridor management for each participating entity. In this way, corridor managers can approach corridor management as a balancing task of (1) enhancing the overall societal value of the corridor while (2) addressing trade-offs among stakeholders regarding beneficiaries and sponsors of a corridor strategy. *NCHRP-917: Right-Sizing Transportation Investments - A Guidebook for Planning and Programming* offers interactive calculators and a detailed method for evaluating strategies using stratified return on investment to determine the “right-size” of an infrastructure system or program.[9] A stratified return on investment approach accounts for both public and private revenues. The stratified approach considers public and private debts, identifying payoffs to all stakeholders for the corridor in terms of benficial asset conditions (APP 2.8.6). Alternative solutions are compared so that stakeholders can make a fully informed set of choices regarding future investments in the corridor.

Corridor Value within Larger Decision Processes: The corridor balance sheet provides a mechanism for making the business case to include corridor improvements within larger processes. Because metropolitan planning organizations (MPOs) and state Departments of Transportation (DOTs) and other entities do not typically program improvements for “corridors” per se, but rather within the context of a larger State Transportation Improvement Program (STIP) or Transportation Improvement Program (TIP), the balance sheet can present the case for corridor solutions within a larger investment management strategy. Furthermore, use of the balance sheet greatly simplifies the ability to articulate purpose and need for individual projects and NEPA and other processes. The decision-support flowchart developed for this project provides guidance for acting on strategies developed to enhance corridor value as part of a larger system (APP 2, Figure 27).

[9] National Academies of Sciences, Engineering, and Medicine, *NCHRP-917: Right-Sizing Transportation Investments - A Guidebook for Planning and Programming* (Washington, DC: 2019), https://doi.org/10.17226/25680.

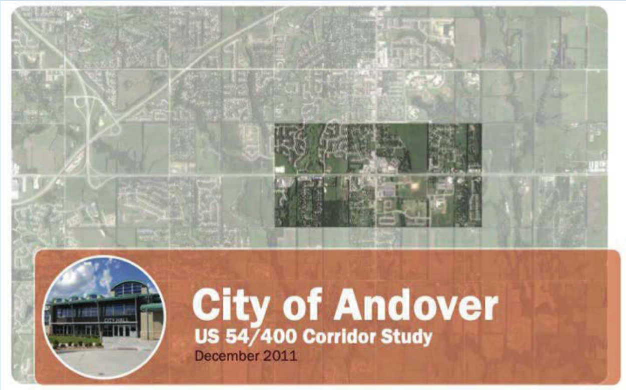
Account for Technology

A *Technology Readiness & Utilization Report Card* has been developed to help corridor managers identify how ready a corridor is to add specific technologies to its balance sheet of assets. This tool is web-based and available through a desktop mobile application which includes a series of questions about the corridor that help determine what elements and potential applications a corridor contains and then calculates a score for the corridor to determine its CAV readiness.[10] The self-assessment is 23 multiple choice questions in which the responses correlate with a score of zero (0), one (1), or two (2) (APP 5.11). The cumulative score indicates the corridor's readiness with a score of less than five (5) being "Low Tech" and at the beginning of a CAV readiness journey, between five (5) and 17 being "Moderate Tech" with opportunities for additional technologies, and above 17 being "High Tech" and having several of the applications already deployed.

Following the self-assessment, corridor managers can follow a "recipe" for CAV readiness with a step-by-step guide on how to prepare a corridor. Steps include 1) inventorying existing traffic signals for signal technology components, 2) establishing a communication protocol with appropriate agencies and departments, 3) installing advanced traffic management system (ATMS) software, 4) hardware/software installation to broadcast CAV information between the signal and CAVs, and 5) installation of CAV applications. For corridors that are in the "High Tech" range, recommendations are given as to additional CAV applications that can be integrated into the corridor such as safety, weather, emergency response, pedestrian, and bicycle detection to name a few.

[10] Modern Mobility, "Technology Readiness and Utilization Report Card," (2021), https://modmob.shinyapps.io/Technology_Readiness//.

Case Example: US-54/400 Andover, KS



Since 1997 a portion of US-54/400 in south-central Kansas has been the subject of a corridor management agreement between state, MPO, and local regulatory partners. One study identified existing and desired land-use patterns, existing and desired highway and street infrastructure, developed an access plan, and promoted a partnership approach with developers and other private stakeholders. The inventory of the land-use characteristics included both the existing condition and market pressures and future desired land-uses and development opportunities.[11]

"The City of Andover, Kansas in collaboration with the Kansas Department of Transportation and the Wichita Area MPO initiated a two-and-a-half-mile corridor study along US 54/400 from159th Street (Sedgwick/Butler County line) to a half-mile east of Prairie Creek Road. Increased traffic from the growth occurring in adjacent Sedgwick County and the City of Wichita as well as western Butler County and the City of Andover is straining existing transportation infrastructure. This US 54/400 Corridor Study is the next step to identify and preserve a corridor footprint for future construction. The study also includes an urban design analysis to provide direction for the integration of land-use and transportation, and corridor character principles to provide direction of the overall character of development for the City of Andover. US 54/400 bisects the City of Andover, and the City is concerned about the impact an expanded freeway footprint will have on its ability to maintain and promote the small-town quality of life it is known for. Drawing dense new development to the US 54/400 corridor will capture a high volume of new vehicle trips within the east-west corridor, minimizing increased congestion on the north-south roads. This would preserve the character of the City of Andover while providing an economic development catalyst to increase municipal revenues.

To accommodate the increased density envisioned for the corridor a robust transportation network is needed. Representatives from the City of Andover, Kansas Department of Transportation, Wichita Area Metropolitan Planning Organization, Federal Highway Administration, Butler County, Sedgwick County, and the City of Wichita with input from public officials and other stakeholders developed and evaluated four horizontal roadway alternates and two vertical alternatives. Traffic analysis, corridor uniformity, driver expectancy, and safety determined that the preferred alternative was providing three full interchanges at the mile line roads (159th Street, Andover Road, and Prairie Creek Road) with frontage roads. Public officials and the community recommended depressing the freeway section under Onewood Drive, Andover Road, and Yorktown Road despite the additional construction, operational, and maintenance costs associated with this option."

[11] Parsons Brinckerhoff, Inc, "City of Andover US 54/400 Corridor Study" (December 2011), https://www.andoverks.com/DocumentCenter/View/1294/Andover-US-54-Corridor-Plan-Report.

PLAY 3 Build Durable Coalitions and Processes

While individual agencies can undertake corridor management, coalitions have emerged as a powerful mechanism for achieving corridor visions over time. Coalitions are important because (1) involving multiple partners they can enable a corridor vision to endure changes in administrations or political conditions, (2) they combine the authority, intelligence, and resources of multiple jurisdictions, (3) they hold an institutional knowledge of how and why corridor performance is important to different partners and (4) the can provide legal and administrative mechanisms for accountability in the long-term management of corridors. Appendix 3.4 documents extensive case research from corridor management efforts throughout the United States where coalitions can range from neighborhood groups surrounding a downtown to multistate coalitions spanning the entire length of the United States.

Secure the Ingredients for a High-Impact Corridor Coalition

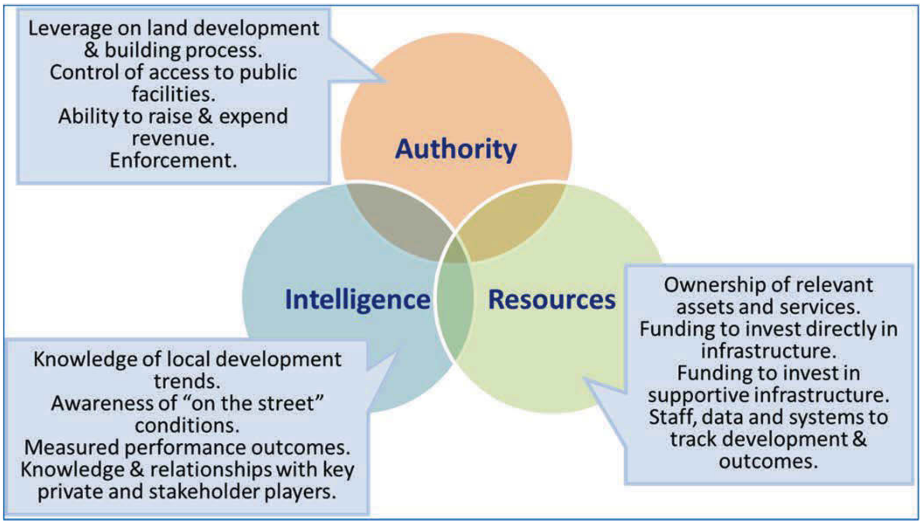


Figure 5: Critical Elements for A Durable and Effective Coalition

A corridor coalition must be more than simply a group of people with a vision and intention to improve corridor performance. Much as fire requires oxygen, fuel, and heat – a corridor coalition requires essential elements of (1) authority, (2) intelligence, and (3) resources in order to affect change towards a corridor vision. Coalition partners should be selected to ensure the appropriate mix of these vital elements. *NCHRP-917: Right-Sizing Transportation Investments - A Guidebook for Planning and Programming* offers a discussion about durable and effective partnerships, citing corridor management as an example of where these three elements have often been successfully integrated.[12] Table 3 from *NCHRP 917* summarizes how different classes of coalition partners can represent an intersection of these key elements.

[12] National Academies of Sciences, Engineering, and Medicine, *NCHRP-917: Right-Sizing Transportation Investments - A Guidebook for Planning and Programming* (Washington, DC: 2019), https://doi.org/10.17226/25680.

Table 3: Key Resources Available from Different Coalition Partners
(Source = Table 8 from NCHRP 917 - Right Sizing Transportation Investments - A Guidebook for Practitioners

Organization	Authority	Intelligence	Resources
State department of transportation	• Control of roadway access • Ownership of right-of-way • Eminent domain	• Data on current and historic state asset characteristics, including – Conditions and improvement history – Traffic volume/ composition – Crashes – Improvement costs – Capacity – Environmental constraints • Statewide travel demand and economic models	• Federal transportation funds • State highway trust funds (where available) • Extensive capital equipment for construction and maintenance • Staff expertise in infrastructure design and delivery
Local government	• Building, zoning, and parking regulation • Property tax, impact fees • Police, fire, and other local services/ enforcement • Influence over utilities, sewer/water, and other requirements for new development • Authority to define business improvement districts, homeowners' associations, and other special districts that may help rightsize facilities • Ownership of local streets and control of ordinances regarding sidewalks, crosswalks, and standards for local facilities	• Land use and zoning maps • Data on development trends and property value • Detailed local area socioeconomic data • Data on public health, crime, and law enforcement activity • Understanding of developer building processes • Knowledge of and relationships with local stakeholders, including the developer community	• Property tax revenues • Potential revenue from other locally implemented revenue mechanisms (e.g., value capture) • Local facilities (such as police stations, libraries, and town halls) as well as parks and open space • Eligibility for community grant programs not available to DOTs
Transit authority	• Operating authority over transit routes • Operating control of stations and transfer facilities	• Knowledge of schedules, ridership trends, and first-hand knowledge of modal shifts • First-hand knowledge of driving and travel conditions	• Operating revenues to run transit services • Vehicles and equipment • In some cases, right-of-way surrounding stations and tracks
Major employers, land owners, developers	• Freedom to buy and sell property at will, relocate activities and trip destinations based on business objectives. • Authority to establish work rules, for example, work hours, telecommuting, and parking restrictions • Wide property rights to use private land as they see fit (or to allow or deny shared or public uses for transportation supportive purposes)	• Understanding of market shifts that provide incentives for where and when economic activity will occur • Understanding of the role transportation performance and amenities have in business location and business growth. Proprietary information about trips, destinations, and traveler segments. • Models regarding consumer preferences in destinations, experiences, and market participation	• Fast access to business revenues and financial assets without long processes needed by public agencies • Analytical resources (software, etc.) to predict and analyze markets

Select Partners Appropriate for the Context

Effective corridor coalitions rarely form spontaneously. Effective coalitions can evolve out of common political or economic interests and must include the key elements shown in Table 3 above. An essential task is identifying parties to be involved in the coalition. Establishing context is the first step to selecting appropriate partners. Corridor context refers to characteristics of the transportation network and its interrelationships with community local governments; local, state, and regional economic systems; and elements related to quality of life including health, natural environment, and the equitable well-being of community members (APP 4.3.1).

Community Context- refers to the nature of a community's built environment, its social and cultural characteristics, its schools, its housing stock, and its disadvantaged populations. Consideration should also be given to whether it is urban, suburban, ex-urban, or rural, whether the land-uses are industrial, commercial, residential, or combinations of the above; when understanding context, it is important for agencies to think broadly and inclusively.

Economic Context- refers to the corridor's relationship and contribution to the local, regional, state, and interstate economy.

Health and Livability Context- can be included with other contextual topics like community or kept separate. Keeping the issue separate can help highlight the topic if it's important to communities. Issues to consider could include whether an area is designated as a nonattainment area, non-auto access to lifeline services, whether development and infrastructure patterns accommodate or encourage walking and cycling, etc.

Natural Context- is meant to explore natural features that contribute to the character and aesthetics of the community- parks, trails, open space, etc.

Transportation Context- includes features like facility type, functional classification, freeway, and arterial spacing, operational characteristics, state of the asset, accessibility characteristics, corridor purpose (home to work, goods movement, etc.), what modes are present, etc.

Establishing corridor context is an exercise in stepping outside comfort zones, and listening to and embracing stakeholder perspectives.

Align Management Roles with Stakeholder Perspectives

When coalition partners join in a corridor management effort, designating key roles and expectations of partners offers the "glue" by which a coalition can provide a mutually beneficial compact for achieving objectives. Communication, Coordination, and Partnering (CC&P), as a unified concept, is the core of successful designation and realization of corridor management roles (APP 4.3.5). Establishing a unified vision and impact measures for managing a single corridor at the local level, let alone a complex system of corridors over a wide geographic area, is no easy task. Planning frameworks can outline decision-making processes, but if considerable thought is not given to the CC&P element, or if the CC&P component is poorly executed, durable, value-added outcomes will be difficult to achieve. Issues to think through include, but are not limited to 1) how to manage intra-agency relationships, 2) how to involve agency leadership, 3) how to conduct inter-agency communications, 4) how to engage federal partners, 5) how to engage stakeholders, and 6) how will the agency ensure that the roles and perspectives of key internal and external stakeholder are in alignment.

Value – The process of establishing corridor context, regardless of the scope and scale of the effort, is an iterative process that will take commitment and patience from the sponsoring agency. Some of the key-value characteristics derived from a stakeholder engagement process include a 1) shared contextual understanding, 2) shared vision for the corridor, 3) shared impact measures, and 4) cohesive corridor coalition with aligned roles.

Outcomes – CC&P is a crucial process for creating a shared sense of value. Engaging stakeholders at the front end has the benefit of developing a comprehensive set of corridor strategies, or solution sets, to improve corridor performance. These strategies can include both supply and demand-side approaches, policy initiatives, land-use proposals, etc.

Identify Impact Indicators for Each Group

State DOTs are increasingly expected to support community development, economic vitality, equitable outcomes, and the overall quality of life of their constituents, in addition to transportation system users. In many cases, the information and authority to serve such users are beyond the jurisdiction of a DOT. For this reason, defining desired outcomes and impact measures for each coalition partner represents an opportunity to both establish buy-in and create a holistic understanding of performance. A coalition vision for corridor impact begins by meaningfully engaging stakeholders to establish a shared contextual understanding of the corridor, as described above and then using that understanding to establish a shared vision for the corridor.

From the shared vision, coalition partners can set goals for how the transportation facility can, and should, support the shared vision. From these goals, objectives are developed, and from the objective's corridor-improvement evaluation criteria and performance, impact indicators are established. In this way, the coalition partners determine how transportation facility improvements will be evaluated. It is important to note that for the transportation facility improvements to work effectively it may depend on non-corridor improvements and this is a clear risk for the DOT. As such, some form of agreement between the coalition partners is needed to help minimize these risks and create a durable solution.

Transportation agencies are adept at using mobility-centric performance indicators and the data for those indicators is readily available. However, what if one of the community goals is land-use change? While data is available to track such changes, it could take a considerable period before those changes are realized. How agencies and their coalition partners reconcile the temporal disparities between the two performance indicators will need to be addressed (APP 4.3.3).

Follow Programmatic Steps to Build a Coalition

If the obligations, contributions, and objectives of the coalition are not clearly understood, partners can lose interest, become overwhelmed by the effort, or fail to understand and offer a vital contribution. Framing early discussions with coalition partners around a blueprint with the "Why, Who, What and How" of a corridor management effort establishes a foundation for the payoffs, roles, and obligations associated with coalition membership.

Key programmatic steps in forming or updating a corridor management strategy require the practitioner to address five essential questions regarding any given corridor management process. These include:

- **What is the realistic scale, geography, and complexity of the intended corridor impact?**
- **What are the roles of key entities in the corridor management process?**
- **How are impacts to be understood over time, and at what junctures?**
- **What are the data and technical resources needed or available to assess impact?**
- **How, when, and to who are corridor impacts to be communicated?**

Figure 6 offers a checklist to guide practitioners through initial discussions with potential coalition partners, including questions to be addressed and a way of conveying the general process that partners can expect in corridor management. Appendix 5.2 offers a discussion of how this framework can be applied with coalition partners for a robust and sustainable collaborative corridor management experience.

NCHRP 08-124 Corridor Framework

What is Important				
Purpose	How we establish a corridor management structure? (Vision and Objectives)			
Goals	How will you know you've arrived?			
Impact Measures	What will we monitor and how will we measure performance?			
Color *Key*	*Why*	*Who*	*What*	*How*
Framework	Why do we care? Who needs to help? What is required to get there?			

The Framework

Decision Points	Attributes	Recipes
What is the nature of the corridor to be managed? **Scale and geography**	☐ Define Corridor- scale & geography ☐ Context of the corridor ☐ Complexity- scale, geography & context	Local, regional, state, intra-, inter- Transportation, Community/Land Use, Safety, Health, Economic, Operations, Maintenance, Equity/Diversity, Natural Resources, Congestion, Accessibility
	☐ Corridor stakeholders	Local Gov, MPO & DOT
	☐ Interested parties	Public, private, ...
Corridor vision, goals, objectives, and impact measures		
What is the role of each partner in meeting the vision? **Alignment with roles**	☐ Managing entity	Role & authority managing entity
	☐ Stakeholders	Roles of stakeholders
	☐ Interested parties	Roles of interested parties
	☐ Corridor context ☐ Vision, goals objective, & measures	Establish w/ partners- breadcrumbs... Supply, demand, or both?
	☐ Governance Mechanism	Agreement type- charter, ILA ...
	☐ Interrelationships	Attributes- durability, priority
What performance is measured and monitored? **Times series management**	☐ Value & weighting of impact measures	Based on context & discussion of value
	☐ Monitoring and measuring	Short, medium, or long-term measurement?
	☐ Data standardization & analysis	Baseline to build scenarios
	☐ Distinguish causation & forecast ☐ Linkages	How the pieces fit together, between organizations/measures
	☐ Prompts & triggers	Why and when to consider?
Data governance and organization	☐ Availability & cost	At different scales of analysis
	☐ Sources of data & granularity	Storage
	☐ Qualitative	How to use and measure?
	☐ Governance	Storage, auditing, ...
Communications	☐ Federal relations	Impact on Federal PMs? After actions
	☐ Public relations	How and when to engage?

Figure 6: Corridor Framework

Implement a Framework for Governance and Accountability

In addition to conveying a common understanding of the roles, extend, and mechanics of the effort, a durable coalition entails a process for partners to commit through a formal accountability structure. NCHRP Synthesis 337[13] finds that 59% of surveyed agencies enter into cooperative agreements for corridor management. These agreements have taken the form of memoranda of understanding, maintenance agreements, development agreements, intergovernmental agreements, resolutions, and others. Sources of authority binding coalition partners together have ranged from general agency powers to specific agency powers, specific enabling legislation for a corridor coalition, specific agency policies and procedures recognizing a corridor, or unbinding voluntary cooperation among partners.

I-15 Case Study

The I-15 corridor (APP 3.7) in the western US provides an excellent example of both multistate and regional coalitions working to improve the overall performance of the corridor. The multistate coalition is called the I-15 Mobility Alliance.[14] The Alliance began as a means for the operations divisions of Caltrans, Nevada DOT, Arizona DOT, and Utah DOT to coordinate their activities along the corridor. The alliance has since expanded to include planning for future improvements such as truck parking, alternative routes (Figure 7), etc. along the corridor. A regional example includes a coalition of the Utah DOT, the Mountainland Association of Government, the Wasatch Front Regional Council, the Utah Transit Authority, the Federal Highway Administration, and adjacent local governments that formed a coalition to evaluate the future improvement to the I-15 Corridor in Davis, Salt Lake, and Utah Counties. This coalition followed a very similar path to the one outlined in this play. They conducted a corridor study called the Wasatch Front Central Corridor Study (WFCCS), which resulted in the development of a solution-set of improvements for the corridor over a 30-year planning horizon.[15]

Figure 7: I-15 Mobility Alliance Alt Rt Study (2017)

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13 National Academies of Sciences, Engineering, and Medicine, *NCHRP 337: Cooperative Agreements for Corridor Management* (Washington, DC: 2004), https://doi.org/10.17226/23332.

14 *"Home - I-15 Mobility Alliance," I-15 Mobility Alliance, January 9, 2020, https://i15alliance.org.*

15 "Final Report Summary," Wasatch Front Central Corridor Study, accessed October 22, 2021, https://wfccstudy.org/.

PLAY 4 Build a Spatial Analysis Environment

Because corridor management involves not only infrastructure, but its users and stakeholders – spatial analysis of the corridor market area is a vital feature of managing corridors for impact. By creating a practical and flexible spatial environment for mapping, displaying and evaluating relationships between users, activities, assets and costs in a corridor, managers can both diagnose needs and illustrate the impact of the management effort. A key play for successful corridor management entails (1) establishing the mapping and spatial resources for understanding the corridor environment, (2) identifying spatial data sources and capabilities within the coalition and (3) agreeing to the layouts by which the coalition will examine and communicate about how the corridor relates to outcomes in its spatial proximity.

Geospatial corridor analysis is visual and helps agencies and stakeholders see what conditions look like prior to any corridor management efforts, as well as after completion of projects. It is beneficial to planners and decision-makers at transportation agencies seeking to understand where to apply or adjust corridor management efforts because it provides the ability to:

- Find candidate project locations based on visualizations (i.e., maps) that communicate mobility, safety, environmental, and economic benefits in ways that reach stakeholders effectively.
- Understand base-level, existing conditions of a corridor's performance and score potential projects across condition and performance outcomes for the same geographic area.
- Plan and prioritize investments in capital projects (e.g., pavement or bridge reconstruction, intersection or interchange projects, highway expansion projects), operations treatments (e.g., Transportation System Management and Operations [TSMO]), and maintenance projects (e.g., pavement or bridge rehabilitation,) in accordance with corridor needs.
- Visualize or display before and after results to measure and evaluate the impacts of projects on corridor performance.
- Study future investment and travel demand option scenarios and demonstrate them visually.
- Pinpoint problems to attack through potential projects by using existing mapped databases that identify locations with multiple deficiencies (e.g., pavement, bridge, congestion, safety) or opportunities (high freight value, developer interests).

Play 4: Build a Spatial Analysis Environment is derived from a more comprehensive guide on spatial analytics for corridor management, included as Appendix 12, *A Framework for Creating the Spatial Environment for Quantifying Corridor Impacts*. Specifically, Appendix P4.1 details:

- Why Establish Spatial Corridor Management Impact Analysis
- Key Steps Needed to Establish a Spatial Corridor Impact Computing Environment
- Advice for Creating the Spatial Environment for Quantifying Corridor Impacts

Understanding Spatial Corridor Impact Analysis

Tools are available to support corridor management projects and planning efforts in setting up the appropriate, relevant measurements. These are explained in detail in Step Five of Appendix 12 (APP 12.3.5). One such tool (featured in Appendix 5.3) is the TOol using STAcked DAta (TOSTADA), which combines geospatial data into an output or score that helps to indicate the performance of a corridor.[16]

Spatial analytical tools are relevant to transportation agencies when they:

- *Use data conflated to highway segments* - Geospatial tools should build spatial environments relying on data conflated to the highway network segments for a corridor to make use of federal mobility, safety, and other data that are measured for those segments.
- *Rely on using spatial resources to develop results* - Tools that help corridor management agencies build spatial environments, like TOSTADA, can layer datasets for measures such as congestion, safety, pavement condition, bridge condition, economic value, and freight value. These interrelated performance data are layered using spatial resources, which can range from ArcGIS to Tableau to SAS to Excel. This provides consistent information on topics of interest and presents them in one holistic picture of performance, instead of considering each performance area separately.
- *Present data visually in a comprehensive score for decision-makers* – By building a spatial environment for corridor analysis, performance calculations for various data layers can be turned into an index between zero and one and have a weighting applied to each segment. The outputs can then be visualized in color-coded data maps to show the combined performance for each segment of a corridor.

Too often, corridor management discussions are focused on engineering evaluations when important economic and quality-of-life concerns may be addressed by the projects, programs, and policies being considered. Because spatial environments integrate maps and other visuals, they provide a more comprehensive and consistent set of information that can improve project comparison and selection, public engagement, and awareness of the relationship between mobility, safety, freight, economic value, and asset conditions.

Applications of Spatial Corridor Analysis

The following provides two examples of building spatial environments for corridor analysis through the TOSTADA tool. TOSTADA is a tool that allows corridor management agencies to understand the full need for, and effects of, transportation investment either in capital projects or operational/TSMO treatments.[17] TOSTADA and the applications of it explained here are described in more detail in Steps Five and Six of Appendix 12 (APP 12.3.5 and APP 12.4.3). Following the steps described for each, a transportation agency can use its own data to apply the

[16] Texas A&M Transportation Institute (TTI), Improving Resource Allocation Through Layered Data Analysis: Final Report, (College Station: Texas A&M University Transportation Policy Research Center, 2017), http://tti.tamu.edu/documents/PRC-14-27-F.pdf.

[17] Tim Lomax, "TOSTADA Data Integration Framework (TOol using STAcked DAta," (Presentation at the National Travel Monitoring Exposition and Conference (NaTMEC), 2018).

steps to any corridor. The applied examples help show how to do this most effectively, but an agency will want to determine the areas of focus and weighting based on its goals and objectives.

I-695 in Maryland Case Example

A TOSTADA proof of concept was developed for I-695 in the Baltimore region for the Maryland Department of Transportation (MDOT).[18] The analysis considered the following five data layers:

- *Congestion* – Using DPM as a performance measure, congestion levels on segments in the corridor were compared on a scale of "good" (colored green) to "bad" (colored red). Annual congestion costs were also computed to provide an indication of the costliest segments along a corridor based on hours of delay.
- *Safety* – Focusing on property-damage-only (PDO) and injury crashes allowed for comparison of crashes by segments of the corridor, which identified the worst-performing sections in terms of safety.
- *Pavement Condition* – Corridor segments were ranked for asset condition using MDOT's grading scale and International Roughness Index (IRI) for pavement quality
- *Bridge Condition* – Using the worst bridge deck condition rating within a road segment, bridge condition was shown in a data layer. The rationale for using the worst condition rating on a segment is that the performance of the entire segment is "only as good as its weakest bridge."
- *Freight Value* – Using daily truck volumes from FHWA's FAF and annual truck commodity value (calculated from corridor truck volumes combined with FAF information), this layer illustrated the dollar value of truck commodities carried on road segments.

As Figure 8 shows, the spatial environments that were built for each data layer allowed planners and decision-makers to evaluate the I-695 corridor's performance on a scale of "good" (colored green) to "bad" (colored red). This was helpful to rank segments and prioritize corridor treatments that would target multiple condition and performance measures. While any one data layer could have been considered independently, looking at them together was helpful to both: (1) assess the corridor as a whole; and (2) identify those segments, based on the combinations of relationships, that are performing or in need of corridor management treatments.

[18] TTI, *TOol using STAcked DAta – The TOSTADA Final Report* (College Station: Texas A&M University Transportation Policy Research Center, 2014).

I-45 Corridor in Texas - TOSTADA

The TOSTADA approach was applied as a demonstration to the I-45 corridor in Texas from Galveston to Dallas. Data were collected for the following four data layers for each highway segment along the corridor:

- *Freight Commodity Value* – a Freight Analysis Framework (FAF)-based value for commodities that are flowing on a corridor, estimated based on roadway type.
- *Congestion* – a value based on Delay Per Mile (DPM), a defensible, industry-tested and approved measure of congestion weighted by volume of traffic and normalized by mileage.
- *Economic Value* – the value of GDP in the county where the highway segment is located in relation to the state's GDP.
- *Pavement* – the score of the pavement quality along the corridor.

The TOSTADA analysis entailed the following steps:

1. A value was assigned for the four layers for each segment of I-45. These values were scaled from smallest (zero) to largest (one) to appropriately compare across the layers.
2. A base index was developed to show what the index is with all four categories weighted the same (25 percent).
3. Three more scenarios were developed to show the corridor's performance when each category is weighted higher than the others.

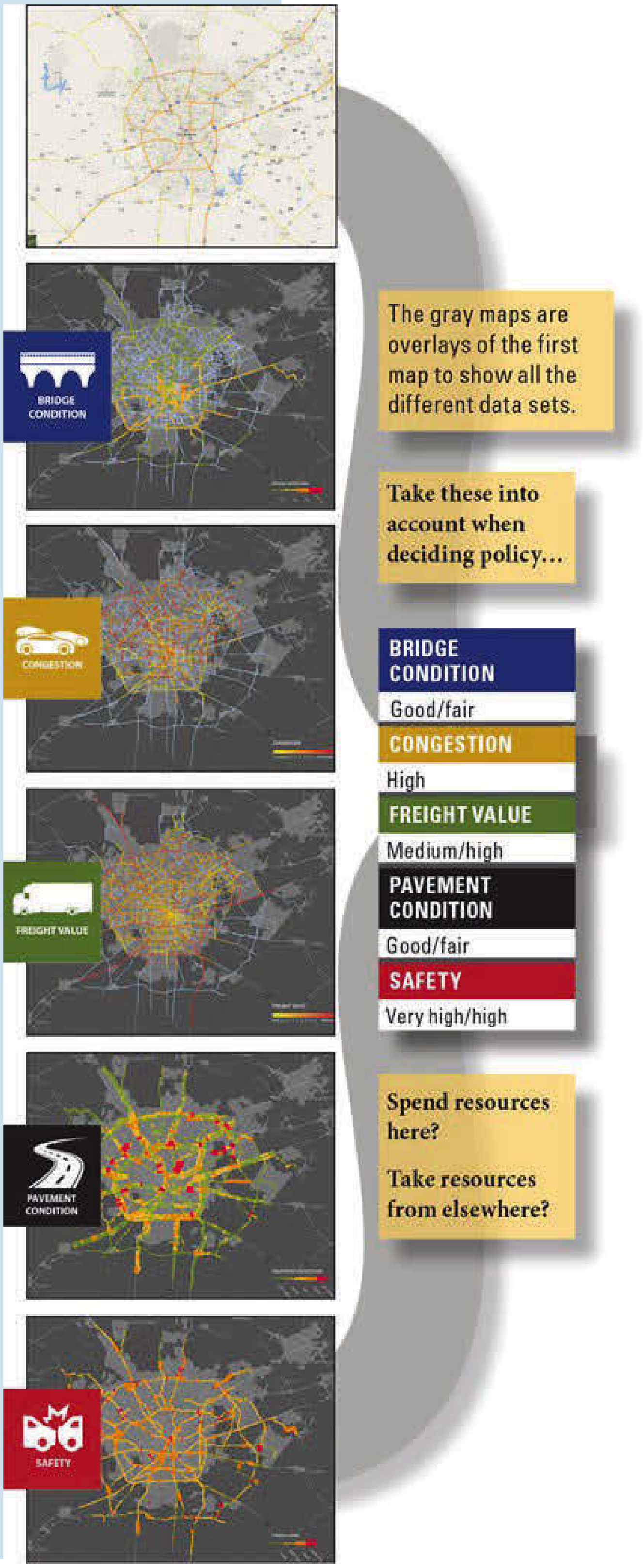

Figure 8: Spatial Environment Created for the I-695 Corridor in Maryland Using TOSTADA

Table 4 below shows the varying weights attributed to the base and alternative scenarios:

Table 4: Base and Alternate Scenarios Used in TOSTADA Analysis

Scenario	Focus Measure	Measure Weighting			
		Freight Commodity Value	*Congestion (DPM)*	*Economic Value*	*Pavement*
One	*Base*	25%	25%	25%	25%
Two	*Freight Value and Congestion*	40%	40%	10%	10%
Three	*Economic Value and Pavement*	10%	10%	40%	40%
Four	*Congestion*	10%	70%	10%	10%

Maps for each of the four scenarios were generated showing the index based on the weighted measures (Figure 9) (high performing). Generally, the maps showed that performance is lowest near the southern end of the corridor in the Houston region. In scenarios one and three, low performance was identified in the middle to the north of the corridor. This analysis helped in discussions about corridor management efforts and the ways they can drive impacts in different ways, and how particular projects, programs, and policies could be incentivized or disincentivized accordingly.

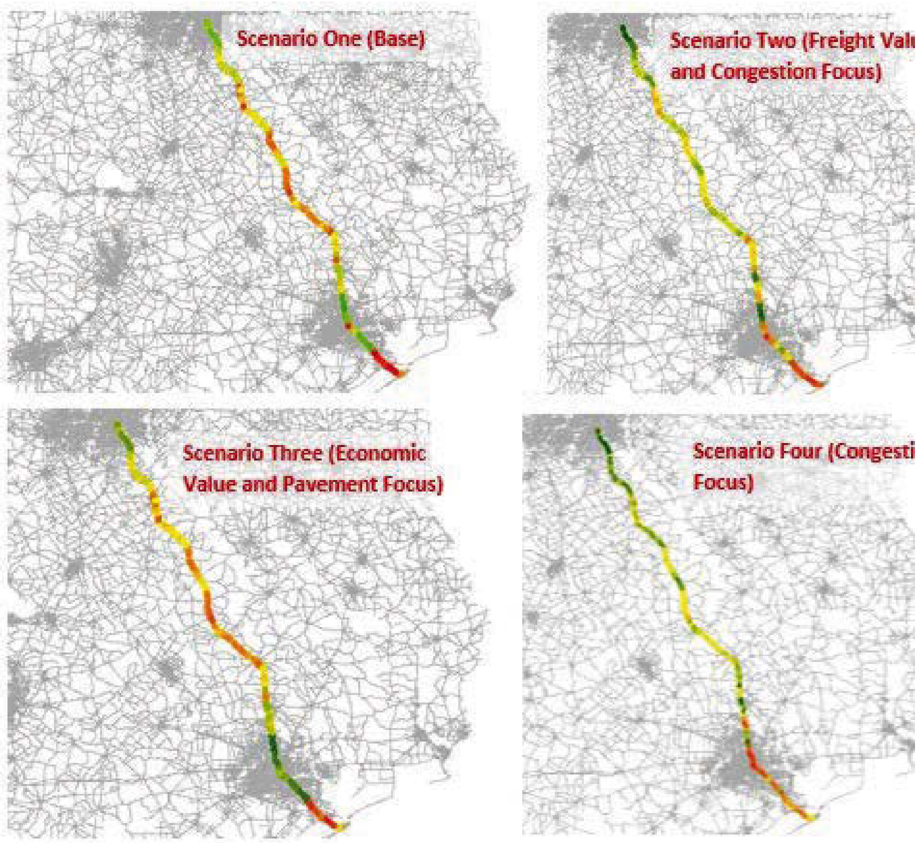

Figure 9: Spatial Environment Created for the I-45 Corridor in Texas Using TOSTADA

PLAY 5 Select Strategies and Supporting Methods/Data

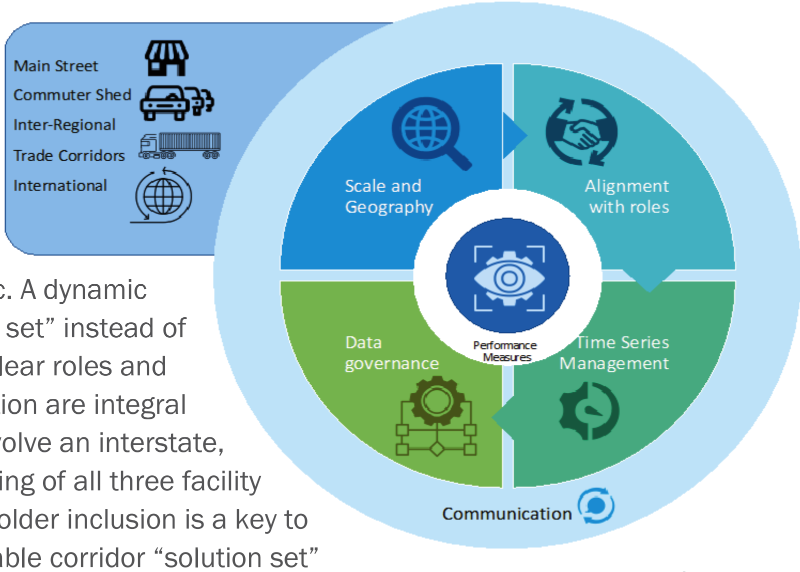

Figure 10: Components of Next Generation Corridor Management Regime

With a coalition (or internal management team) in place – a cohesive vision for the corridors' role and actions for achieving the vision are essential. Because corridor conditions are always changing, a vision is expected to be dynamic. A dynamic vision requires a flexible "solution set" instead of a singular preferred alternative. Clear roles and objectives for each potential solution are integral to success. Such a vision may involve an interstate, regional, or local facility, or a nesting of all three facility types (APP 3.3). Because stakeholder inclusion is a key to developing a durable, implementable corridor "solution set" corridor managers are advised to ensure that the parties needed to develop and implement such a "set" are on board. If not, it is advisable to revisit Play 3: Build Durable Coalitions and Processes, with its framework for engaging stakeholders (both internal and external) and for developing a shared vision of a corridor; one that has been vetted with the leadership of partner agencies, community, and business groups. While no stakeholder engagement process can guarantee a durable outcome, developing a shared vision and agreed-upon goals, objectives, and performance measures/evaluation criteria will certainly improve the odds of successful outcomes. The I-15 case study includes an example of how agency partners and local governments developed a shared vision for I-15 in Salt Lake Co., Utah (APP 3.7).

> **Solution Set-** *A set of strategies {a, b, c, d, … n_1} for improving corridor performance.*

Make an Adaptable Strategy: Flexible Agreements and Trigger Points

In addition to a compelling vision and coalition, two more components of a corridor strategy include flexible corridor agreements and trigger points.

Flexible Agreements: The formation of corridor agreements is addressed in Play 3, however, the nature of agreements should continue to be a consideration throughout the strategy execution process. Corridor agreements define the ongoing stakeholder interests and the roles and responsibilities of each party in carrying out the shared vision as embodied in the corridor solution set. For example, a corridor solution set could include local land-use strategies, so it's important to get a commitment to make those changes. Figure 10 shows the components of a Next Generation Corridor Management Regime.

While the formal document of a corridor agreement may be cumbersome to revisit too often, a strategic summary of the agreement can be a valuable tool for partners to readily identify roles and opportunities to participate, and also review the overall strategic organization of the effort. Table 5 below offers a general format that a corridor coalition can use to create a "coalition at a glance" reference that can be readily checked and updated at coalition meetings and shared with agency leadership. The table shows general types of solutions that partners may contribute and payoffs they may expect, however, use of this table is recommended to be highly specific such that partners can re-visit and refresh understood solutions and payoffs frequently. (For example where the table says "municipal government" a coalition would actually name the government agency. Where the table says "type of solutions" a coalition would specify individual actions to be undertaken and with what frequency. Where the table says "needed payoffs" a coalition would include a specific and quantifiable target with a designated time horizon). Keeping a table of this type current for a corridor coalition enables the coalition members to consistently track activities and payoffs at each juncture, and to identify when and why underlying agreements (or coalition membership) may require change.

Table 5: Flexible Coalition "At a Glance" Table

Coalition Partner	Type of Solutions	Needed Payoffs
Municipal Government	Zoning & Local Streets Parking Tax Increment Financing/Business Improvement Districts Beautification and Enhancements Police, fire, public health, and supporting services.	Preserve Tax Base Attract Business Improve Neighborhood Quality of Life
Private Residential or Business Groups	Business operations (demand management) Private infrastructure and land Use of private land/facilities	Access to Markets Enhanced Property Value Business Amenities & Services Business attraction, recruitment, creation, or expansion incentives.
State DOT	Capital programming Use of right-of-way Provision of ITS or other technologies Beautification or enhancements	Achievement of performance-based planning objectives
Transit Agency	Service and Route Operations Inter-Modal Connections Integration of Operations with TNC or Parking Solutions	Farebox Recovery Efficient Operations Enhanced Modal Capture
Port Authorities	Expanded capacity or amenities Adapted operations/time-of-day Sharing of market/operational information and technology with other partners	Port Revenue Enhanced Port Access Efficient Operations Enhanced Modal Capture

Trigger Points: Corridor agreements can also be used to periodically reconvene the stakeholders to assess progress toward implementing a corridor solution set. Importantly, corridor agreements can also make it more difficult for new players to change course, whether at the local government or agency level. With that said, it's important to realize that things do change, and practitioners would do well to establish a process that accounts for changing conditions. This is where the concept of trigger points comes into play. Trigger points are times in the corridor development process where changing conditions may warrant a reassessment of the corridor vision, goals, objectives, performance measures/evaluation criteria, and the components of a solution set. Trigger points can be event-driven, time-driven, due to leadership changes, or when the stakeholders agree that it is necessary to reassess. Table 6 below gives an example of how trigger points can be organized in a corridor coalition to condition-specific actions at measurable points in a corridor's development.

Table 6: "Trigger Point" Table

Performance Issue	Current Solution	Trigger Point	Alternative Solution
Inadequate Parking on Urban Blocks	Provide overflow shuttle at peak periods	Development Density Exceeds pre-determined threshold	Provide transit and park-and-ride service
Lack of Truck Capacity Accessing Industrial Park	Businesses stagger hours and shifts and use traffic control officers	Business park exceeds pre-determined threshold of employment	Reconstruct site access and intersection into park
Pavement Condition on Statewide Interstate System	Provide asset management/preservation on schedule A	AADT at state cordon points indicates growth exceeds X%	Switch to asset management/preservation schedule B

In each example of Table 6, the corridor benefits from not a singular solution but a "solution set" identified in the corridor planning process. The solution set is based on needs ascertained through ex-ante modeling of anticipated conditions as described in Play 1: Define the Corridor and Its Impact, yet includes alternative solutions given both aggressive and likely forecasts. Through benchmarking corridor conditions (in the case of Table 6 development density, size of an industrial park, or AADT pattern on an interstate system), coalition partners can be ready to pivot to different solutions as demand, technology or markets change.

Balance the Demand and Supply Sides of the Equation

Corridor management is not simply a process of enlisting coalition partners in a program of building infrastructure. In many cases, lower-cost solutions can occur simply through partners operating existing infrastructure or business processes strategically. In a solution set approach to improving corridor management, it may take both demand-side and supply-side approaches to address current and future growth (APP 3.2.2).[19] Figure 11 below offers examples of different types of approaches that managers consider as a starting point for a solution set balancing infrastructure supply and travel demand.

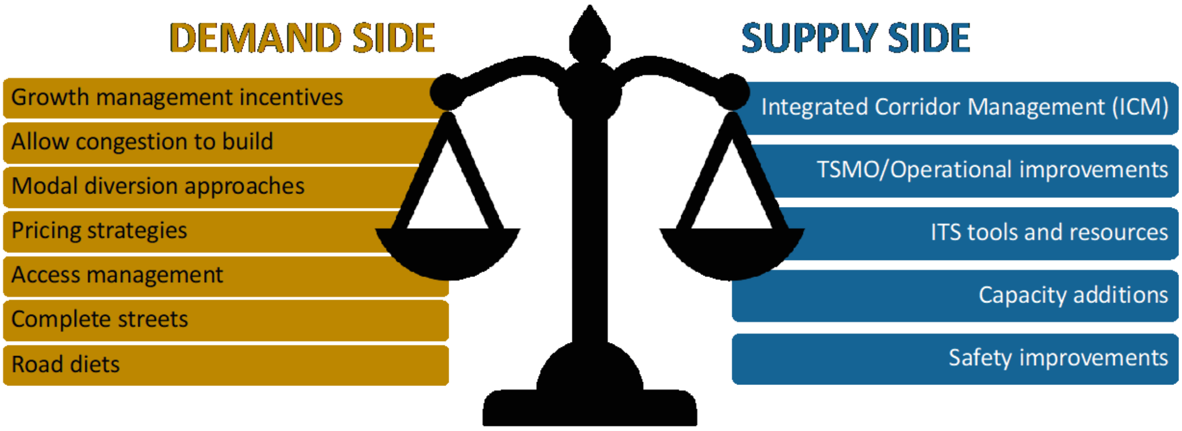

Figure 11: Components of Demand and Supply Strategies

Managing Demand- Financial challenges, shifting travel behaviors, and policy priorities are forcing agencies to re-focus on preservation, efficiency, and resilience, creating a compelling case for demand-based strategies that squeeze every bit of capacity out of existing systems. [20] Indeed, some have already developed policies prioritizing exploration of Travel Demand Management (TDM) strategies as a first step in long-range plans and corridor planning processes.[21] This shift in policy, however, often masks the myriad of challenges that agencies will face in a transition to demand-based solutions- increasing the role of demand strategies requires substantial changes in planning and design processes.

Demand in its broadest terms refers to the range of use behaviors that place demands on a flexible system or platform. That makes demand a people-focused approach as opposed to a traditional mobility-focused approach, which focuses on vehicle speed, congestion levels, and limiting access, where who is traveling and why is generally not addressed. Three areas where

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[19] Justin B. Schor, *Building a Multimodal Future: Connecting Real Estate Development and Transportation Demand Management to Ease Gridlock* (Urban Land Institute, 2019).

[20] "ASCE's 2021 American Infrastructure Report Card: GPA: C-," ASCE's 2021 Infrastructure Report Card |, September 13, 2021, https://infrastructurereportcard.org/; Inrix, "Covid-19's Impact on Transportation Trends," Inrix, October 19, 2021, https://inrix.com/covid-19-transportation-trends/; "Fact Sheet: The American Jobs Plan," The White House (The United States Government, May 4, 2021), https://www.whitehouse.gov/briefing-room/statements-releases/2021/03/31/fact-sheet-the-american-jobs-plan/.

[21] "Commute Trip Reduction - Rules, Policy, and Guidance," Washington State Department of Transportation (WSDOT) (WSDOT, September 8, 2020), https://wsdot.wa.gov/transit/ctr/rules-policy; "Regional Travel Demand Management - DRCOG" (Denver Regional Council of Governments, November 16, 2005), https://www3.drcog.org/documents/archive/RegionalTDMPlanFinal.PDF ;"Incorporation of Transportation Demand Management (TDM) into the Development Review Process" (Government of the District of Columbia Department of Transportation, July 2010), https://ddot.dc.gov/sites/default/files/dc/sites/ddot/publication/attachments/tdm-final-report.pdf; "Thrive MSP 2040," Thrive MSP 2040 - Metropolitan Council (Metropolitan Council, May 2014), https://metrocouncil.org/Planning/Projects/Thrive-2040.aspx.

professionals can rethink traditional planning approaches include 1) repurposing traffic management tools (pricing, traffic control devices, etc. to divert or deduct car traffic), to manage demand, not traffic flow, 2) expanding the quality and quantity of participation in ideation to increase opportunities for innovation in problem identification and goal setting, and 3) intentionally build partnerships for implementation from participation efforts. Below are practice examples:

- The City of Austin created a downtown **parking management** approach that utilized existing parking to meet downtown travel preferences for most of its visitors by creating a "park once and walk, bike, or take transit between destinations."[22]
- Similarly, Stockholm's **congestion pricing** strategies are famous- "on the very first day, the impact was obvious—20% of Stockholm's inner city traffic simply 'disappeared.'"[23]

Managing Demand Through 7-D Variables: As mentioned above, community land-use goals can play a large part in shifting demand. The use of "D-Variables" shown in Figure 12 offers a host of demand-side targets for managing the pressures on a corridor enabling coalition partners to enhance performance without being limited to technology and infrastructure expansion options. Table 1 in Appendix 2 describes each of the 7-D approaches for managing corridor demand and how they relate to the corridor management process.

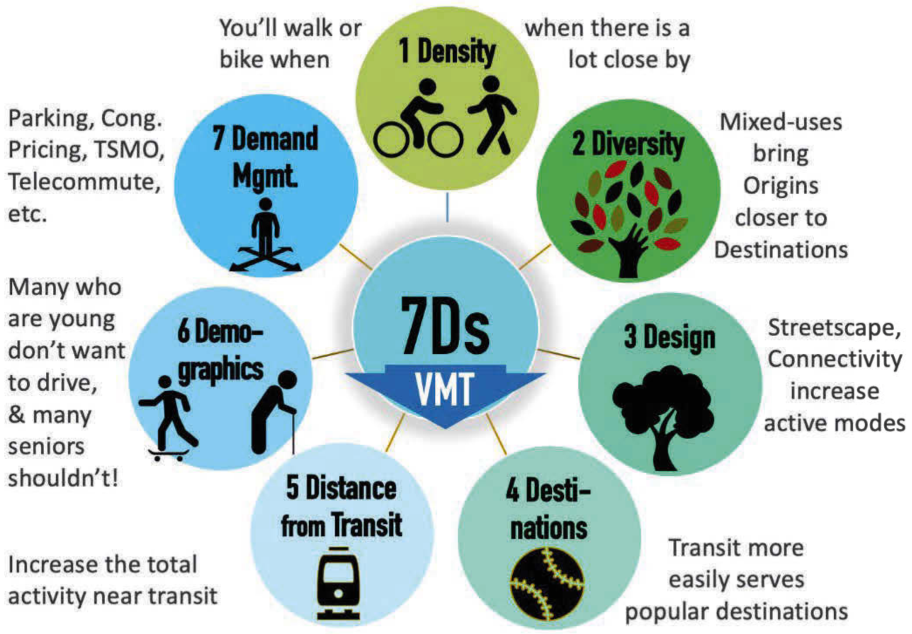

Figure 12: 7-D Variables for Managing Demand

22 "Downtown Austin Parking Strategy - Final Report" (Downtown Austin Alliance), accessed October 22, 2021, https://downtownaustin.com/wp-content/uploads/2019/04/AustinParkingStrategy_Final.pdf.

23 Jay Kassirer and Sharon Boddy, "'Stockholm Congestion Pricing,'" Tools of Change (Cullbridge Marketing and Communications, 2014), https://www.toolsofchange.com/en/case-studies/detail/670.

Appendix 10 provides an interactive calculator that corridor managers can use to test how changes in 5 of the 7 D variables can affect demand and associated performance outcomes on urban or developing highway corridors, with the empirical and statistical documentation of the methodology for deriving marginal effects of D-variables given in Appendix 11. By using these established and quantifiable marginal effects between "D-variables" and highway performance, corridor managers can actively consider demand-side strategies for enhancing corridor performance.

Freight can also play a significant role in balancing demand and supply strategies. To help practitioners better understand the freight context of a particular corridor, the research team modified the meaning of 7D- Mobility variables to account for, and better understand how freight uses in a corridor affect the management, operation, and performance of a corridor. For comparison purposes, a table was created to show the definitions of both sets of D-variables as shown in Appendix 5.5.

Next-Generation Tools and Reference Points for Corridor Improvement Strategies

As equity, demographic considerations, community quality of life, and rapidly changing technological and economic factors increasingly determine the objectives of corridor management, managers require an increasingly agile set of measures for pinpointing and evaluating supply and demand-side tactics. For this reason, effective strategies will aim at a wider range of performance targets than simply reducing delay, reducing crashes, and increasing throughput. The menu of targets for a corridor management effort can include equity, sustainability, quality of life, and economic outcomes supported by known practices in corridor management as well as the evaluation techniques offered in the appendixes of this playbook.

Interactive Resources for Identifying Potential Targets and Evaluating Strategies: Appendix 2.3 provides a discussion about the evolution of corridor management paradigms and how variables beyond simply speed, safety, and throughput have come to define the practice. The appendix also includes an inventory of commonly used performance indicators (APP 2.7, Table 3). Play 1: Define the Corridor and Its Impact explores approaches for defining the scope of a corridor management effort based on the context. From Play 1, an important resource offered for selecting both performance indicators and solution techniques is the *Corridor Orientation Tool* and its associated guidance (APP 7 and APP 8). Another resource offered for identifying successful corridor management practices is the *Corridor Innovation Database*, which readers are encouraged to explore for documented examples of specific corridor management tactics based on the type of performance issues encountered, management objectives, and other contextual factors (APP 9). Play 7: Evaluate the Effectiveness of Corridor Strategies offers guidance on the use of a new suite of corridor performance diagnosis and evaluation tools, fully documented in Appendix 5.

Use Case Research for Selecting Strategies: Corridor managers can benefit considerably from consulting case research of successful practice both for identifying corridor management approaches and relating those approaches to the larger systems to which localized or regional corridors belong. Appendix 3 provides extensive examples of case studies organized by national corridor systems on how specific corridor management techniques have been undertaken to address equity, freight movement, balancing local and national concerns, corridor funding, transitioning from corridor planning to programming, and other topics. One of the case studies evaluated the coast-to-coast I-90/I-94 corridor system (APP 3.4). This case study focused on freight movement and as did all the case studies, included several deep dives into metropolitan areas to assess the management strategies and techniques used by area agencies. Key takeaways from the body of case studies indicate 1) that it is important to understand the scale and geography of a corridor effort, 2) it is important to understand the needs of, and align the roles of corridor stakeholders, 3) changing concepts of performance make it necessary to understand how performance can unfold over time, for example, the temporal difference between measure of congestion and land-use change, 4) data governance/organization and availability are key success factors which can be addressed through corridor governance structures.

PLAY 6 Balance Competing Uses and Sources of Value

A critical play in any corridor management effort entails enhancing each source of value on a corridor without undermining other sources of value. This is especially true when considering business and residential or community interests in a corridor. How will corridor coalition partners balance what might be considered competing outcomes and measure the performance of the corridor? Frequently, the needs of each corridor user are not understood by other users of the corridor. One of the challenges in measuring corridor management impacts is the great diversity in what is viewed as a corridor. Highly urbanized corridors carry mostly person trips that are typically the focus of congestion, incident management, and transit or active alternatives. And, in urban corridors where freight trips are numerically high, they usually represent just a small percentage of the overall traffic volume, yet a limited number of freights carrying vehicles, rail cars, or vessels often represent significant economic value and infrastructure consumption. This complex relationship again points to the need for robust stakeholder engagement, the development of a shared understanding of corridor context, and a shared vision for the corridor.

Expand on the Corridor Balance Sheet

Play 2: Take Inventory of the Corridor introduces the corridor balance sheet as a way of inventorying the assets and liabilities of a corridor, evaluating both a corridor's overall value, as well as pinpointing targets for enhancing value through corridor management. When seeking to balance the uses of a corridor, the balance-sheet technique given in Play 2 may be further enhanced by considering comparative qualitative types of value a corridor can have. A very simple organization of a corridor balance sheet to consider (1) local community value, (2) local business value, or (3) regional/national industry value can enable corridor managers to understand and profile how their strategies seek not only to enhance corridor value but also balance these general principles.

Local Community Value: This can be understood as the value that households, community groups, or local residents derive from using, or being located in proximity to, the corridor. It includes considerations such as livability, walkability, easy access to personal and household amenities. Equitable access and environmental conditions for vulnerable populations can be a significant driver of community value as well. Local community value can be understood as the degree to which a given corridor asset or liability addresses the question: ***Does the corridor make a better place for people?***

Local Business Value: This can be understood as the value that local or regional businesses within the corridor termini derive from the service the corridor provides. It may include considerations such as whether the corridor facilitates needed business operations and deliveries, commuting, customer access, and property value. Business value may often be measured in terms of property value, or the costs of doing business for establishments on the corridor. Local business value can be understood as the degree to which a given corridor asset or liability addresses the question: ***Does the corridor make those directly served more competitive or profitable?***

Regional/National Industry Value: This can be understood as the value that the corridor serves for pass-through traffic, or as a resource for moving people and goods in support of larger trade and commuting patterns. It may include considerations such as the reliability, delay, safety, or resilience of the corridor system's availability to make connections between buyers and suppliers, international gateways, or critical resources available. Regional/National industry value may often be measured in terms of redundancy, delay, same-day delivery radius of surrounding trade centers or communities, or workforce/supplier pools within a reasonable travel-shed. Regional/National Industry Value can be understood as the degree to which a given corridor asset or liability addresses the question: ***Does the corridor play a constructive role in regional, national or global trade markets?***

Table 7 below offers a basic frame for expanding a corridor balance sheet to simply rank on a scale of 1-5 the degree to which each corridor asset or liability may represent either (1) local community value, (2) local business value or (3) regional/national industry value.

Table 7: Corridor Balance Sheet

Types of Indicators	Assets ***Sources of Benefit in a Corridor System*** *(Reported as Annual or Current Year Value)*	Liabilities ***Sources of Avoidable Cost*** *(Reported as Discounted Value over the Time Horizon of the Corridor)*	Community Value	Local/ Regional Business Value	Reg/National Industry Value
Quantifiable Economic Indicators	Infrastructure with residual/replacement value. Facilities generating GDP and value-added activity within the corridor influence area. Key markets accessible to corridor. (Detail Given in Play 2)	Sources of transportation cost for users of the corridor (time, mileage, reliability cost) Sources of transportation cost for non-users (emissions, crashes other wider costs) (Detail Given in Play 2)	*1 = not relevant* *2 = somewhat relevant* *3 = relevant* *4 = highly relevant* *5= essential for corridor success*		
Intangible Indicators	Aesthetic, natural or other qualitative sources of value.	Noise, imposition of inequitable burdens on quality of life, other non-quantifiable considerations.			

Use Decision Clinics to Evaluate the Balance Sheet: NCHRP 917 established *decision clinics* as a recommended practice for ascertaining different sources of value in a transportation system to arrive at a "right-sized" understanding of what a system can be from diverse perspectives.[24] A decision clinic is understood as a process whereby the needs and resources of a transportation system are given a "check-up" from different points of view to assess how well the system is performing from the standpoint of different indicators of health.

If a corridor balance sheet is constructed as shown in Play 2: Take Inventory of the Corridor, managers can establish annual (or bi-annual) *corridor decision clinics* to add a qualitative component of the type shown in Table 7 above. In a decision clinic, the coalition or corridor management would 1) assign a panel of 3-5 beneficiaries of each source of value given above (community value, regional/local business value, and regional/national industry value), 2) present the corridor balance sheet to each panel to evaluate the relevance/urgency of each balance sheet item in terms of their perceived value of the corridor, 3) use the 1-5 weighting of balance sheet items to evaluate and report on both, 1) the overall responsiveness of the management strategy to the corridor's value potential (as given in Play 2) but also, 2) identify any gaps, incongruity, or risks that corridor actions, by improving one area may jeopardize other areas. Recommended steps for corridor balancing decision clinics include:

(1) Complete Corridor Balance Sheet as shown in Play 2
(2) Designate beneficiary classes representing different types of value expected (using Table 7 above as a starting point)
(3) Appoint 3 stakeholder panels to serve as focus groups assessing the relevance of each balance sheet item with respect to each type of value
(4) Facilitate half-day or full-day workshop in which each group separately reviews the balance sheet, assigns relevance/urgency values, and provides qualitative suggestions to the corridor management coalition or team for updates to the management strategy

Clinics of this type can be undertaken with minimal staff resources and can serve as an ongoing check to both ensure that the overall priorities governing the corridor management effort are current as well as draw a managing coalition's attention to changes or threats that may have been missed otherwise.

Consider Innovative Design Techniques

Another opportunity to reconcile competing sources of value in a corridor can be found in the innovative design and management of the corridor infrastructure. While there is an entire literature on context-sensitive solutions, access management, and value engineering, some new insight can be gained in their specific application for balancing personal and business uses through the examples given in Appendix 2.5.[25] Furthermore, Appendix 5.4 and Appendix 5.5 can provide new insight above and beyond the previously published references on these topics.

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[24] National Academies of Sciences, Engineering, and Medicine, *NCHRP-917: Right-Sizing Transportation Investments: A Guidebook for Planning and Programming* (Washington, DC, 2019), https://doi.org/10.17226/25680.

[25] Timothy R. Neuman et al., NCHRP Report 480: A Guide to Best Practices for Achieving Context Sensitive Solutions (Washington, DC: Transportation Research Board, 2002), https://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_480.pdf; Ingrid B. Potts et al., "Design and Access Management Guidelines for Truck Routes: Planning and Design Guide," June 2020, https://doi.org/10.17226/25950; David C. Wilson, "Value Engineering Applications in Transportation," 2005, https://doi.org/10.17226/13869.

Focusing Solutions on Access Density: Figure 13 gives an example of the type of analysis that can be done using the technique given Appendix 5.4 whereby corridor managers can consider each of the functional classifications of roadway within their corridor area relative to the ideal grid spacing suggested in guidance from the Institute of Transportation Engineers (ITE) to consider which functional systems in their sub-area overall may benefit from increased or reduced access density. In the example given (building on the case study in Appendix 3.5.11), it is shown that the VMT capability for principal arterials in the downtown Atlanta region, and the VMT capability for minor arterials and collectors in the I-85 corridor study area, may be compromised by issues of connectivity and access density. The NCHRP guides on context-sensitive solutions, access management, and value engineering cited above can provide further guidance on techniques for addressing such an issue, however, the tools provided in Appendix 5 may lead managers to pinpoint where such solutions can help enhance the overall corridor value.

VMT Capability	SqMi	46.0	
	Downtown		
	Bench	Actual	Pct
Expressway	1,000,000	1,200,000	120%
Principal	500,000	350,000	70%
Minor	400,000	600,000	150%
Collector	30,000	60,000	200%
Total	1,930,000	2,210,000	115%

VMT Capability	SqMi	147.0	
	I-85 North		
	Bench	Actual	Pct
Expressway	1,000,000	1,200,000	120%
Principal	500,000	400,000	80%
Minor	400,000	300,000	75%
Collector	200,000	100,000	50%
Total	2,100,000	2,000,000	95%

VMT Capability per Sq Mi.	Downtown		
	Bench	Actual	Pct
Expressway	22,000	26,000	118%
Principal	11,000	8,000	73%
Minor	9,000	13,000	144%
Collector	700	1,300	186%
Total	42,000	48,000	114%

VMT Capability per Sq Mi.	I-85 North		
	Bench	Actual	Pct
Expressway	7,000	8,000	114%
Principal	3,000	3,000	100%
Minor	3,000	2,000	67%
Collector	1,400	700	50%
Total	14,000	14,000	100%

Figure 13: Access Density Analysis Example

Consider Applications of "D" Variables to Urban Freight: Appendix 2, Table 1 introduces the series of contextual "D" variables for considering new solutions to enhance corridor performance. A literature review (Appendix 1) shows that these contextual variables have not yet been widely applied to explore context-appropriate supply and demand solutions for freight movement. However, there is a growing body of work in the field of Cargo Oriented Development (COD) in which specific indicators of destination access, density, design, modal diversity, demand management, demographics/industry mix, and D-variable considerations can be applied to freight nodes on a corridor.[26] Figure 14 below illustrates a host of urban freight indicators that have been tested by the Center for Neighborhood Technology to COD case studies in Chicago, Memphis, New Orleans, Minneapolis, and elsewhere.

[26] Center for Neighborhood Technology and Ford Foundation, "Freight Train to Community Prosperity Metrics for the Integration of Community Economic Development and Efficient Freight Movement," October 2015, https://www.cnt.org/sites/default/files/publications/CNT_FreightTraintoCommunityProsperity.pdf.

COD Metrics Overview		
A. Local Economic Development	**B. Freight System Efficiency**	**C. Environmental Impact**
Industrial Location Efficiency	Truck and System Productivity	Air Quality
Access for Manufacturers	Travel Time and Reliability	Water Quality
Job Creation and Career Paths	Drayage and Terminal Operations	Noise Level
Worker Transportation Access	Right-Sized Shipping	Lighting
Public Costs and Revenues		Regional Land Use
D. Safety (Affecting All Metrics)		

Figure 14: Source: Freight Train to Community Prosperity, Center for Neighborhood Technology, 2015

Furthermore, Appendix 5.5 offers techniques for assisting corridor managers in identifying opportunities to develop innovative freight solutions through adopting D-variables on statewide corridors as well.

Include Four Functional Areas When Developing Strategies

Once equipped with, 1) a clear view of the corridor balance sheet, and 2) the insight of decision clinics/stakeholders to protect and balance changing sources of corridor value, and 3) an understanding of potential improvements in both design and context, managers can then benefit from organizing a corridor management program to address four general areas of management. These four areas of management focus on:

Regulations and Revenue Actions: These are actions that managers can take to reduce avoidable costs (corridor liabilities) without constructing or changing the physical infrastructure. They may include managing access, invoking local zoning or parking regulatory authority, offering incentives or amenities through tax increment financing, business improvement districts, or other policy instruments.

Planning and Investment Actions: These are actions that managers can take to synchronize local capital improvement programs, on-site investments made by developers or property owners, and enhancements or capital projects undertaken by transportation or transit agencies to add or enhance assets while reducing performance liabilities.

Operations and Maintenance Actions: These are actions that partners can take without constructing or changing infrastructure to reduce performance liabilities or enhance assets by how organizations operate. These may include ride-sharing incentives, accommodations for Transportation Network Companies (TNC's) for business or port curb-access, transit route design, the timing of shifts or deliveries at major employers or industry sites, and other techniques pinpointed through the balance sheet and balancing process.

Design and Construction Actions: These are actions that managers can take to re-design or re-build a corridor. They could include: a major expansion of highway, transit, or port capacity, increases in parking capacity, increased density of private properties/plants, or relocation of major assets (such as moving a convention center into a downtown near lodging and other venues to reduce the mileage of travel or parking requirements on a corridor).

Table 8 offers a simple template for how a corridor management strategy might be summarized and checked to make sure that none of these four areas are overlooked when responding to needs or opportunities identified in updating a corridor balance sheet or devising/updating a strategy. Figure 15 below demonstrates these four areas which may comprise a strategy, and how the different techniques of Plays 2 and 3 and Appendix 5 can support evaluating and developing strategies in each area.

Table 8: Corridor Strategies Check-List

Regulation and Revenue	Planning and Investment	Operations and Maintenance	Design and Construction
✓ Are local partners applying zoning, land-use, or parking regulatory authority? ✓ Are private partners regulating access, parking, or service times to manage performance? ✓ Are state authorities managing access, speed, and other performance drivers?	✓ Are municipal/local comprehensive plans or small area plans aligned with performance objectives? ✓ Do developer site plans and expansion plans account for opportunities to enhance long-term performance? ✓ Are DOT plans and resources aligned with corridor performance needs?	✓ Are transit routes and other services responsive to performance liabilities and leveraged to create value? ✓ Are ITS and Transportation System Management and Operations consistent with desired corridor outcomes? ✓ Are shifts, delivery times, and business operations responsive to corridor objectives?	✓ Are municipal streets, parking, or other locally-owned amenities configured to serve as corridor assets? ✓ Are local plant or district/subdivision plans aligned with understood sources of corridor value? ✓ Are DOT projects configured to minimize liabilities for all sources of value, and enhance the value of not only state infrastructure but other assets as well?

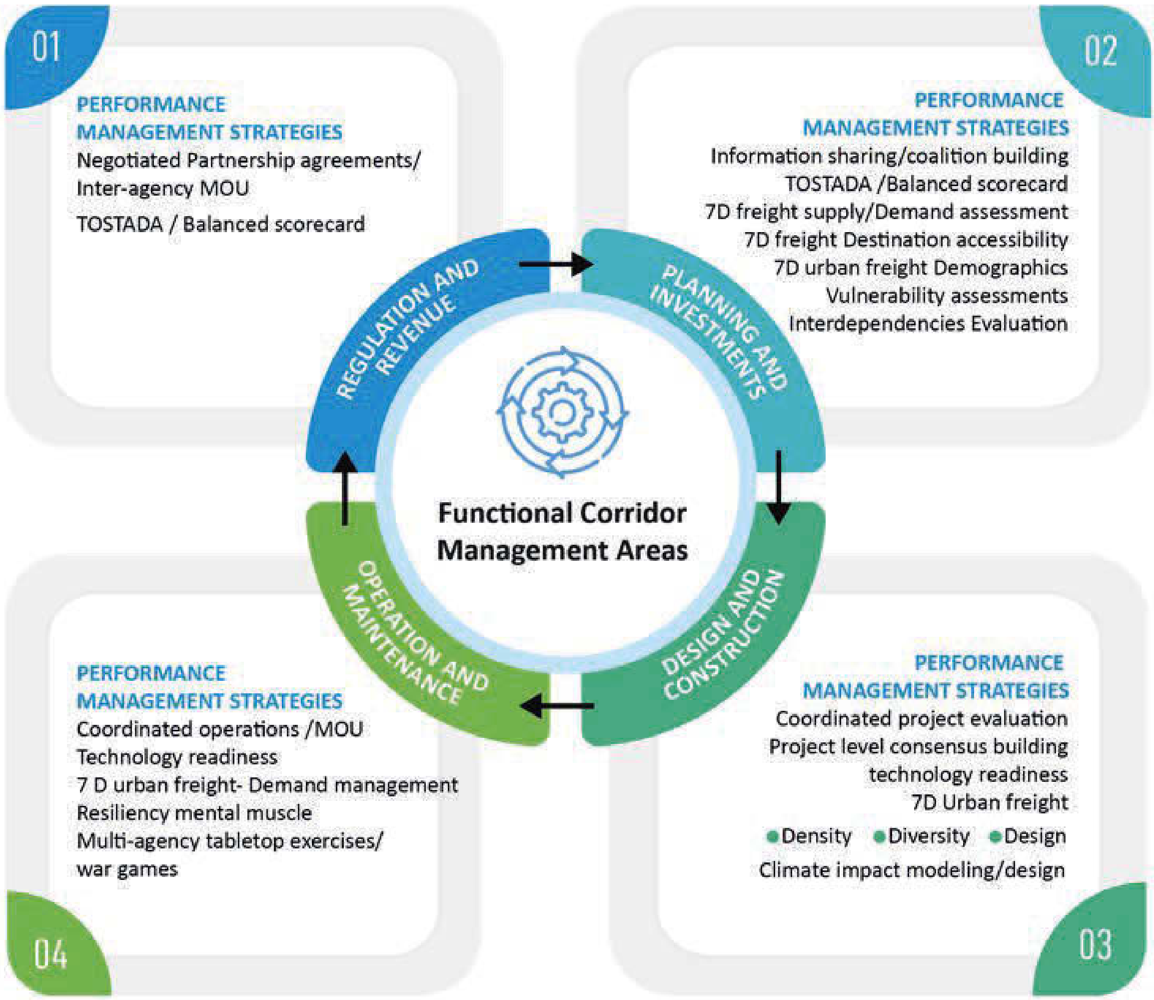

Figure 15: Four Functional Areas of Leverage for Corridor Management Techniques

Case Study: Balancing Freight and Passenger Travel with Community

I-94 and the Minneapolis Upper Harbor- Many communities around the globe grew up around early nodes of commercial transport like port facilities and rail terminals. As a result, the movement of heavy goods often presents community land-use conflicts especially for heavy commodities like scrap, gravel/aggregates, and agriculture products. As part of the I-90/I-94 Corridor Case Study, the research team explored different perspectives and nests of activity across this continent-wide corridor (APP 3.4). While not an initial focus of the research, the team evaluated the Minneapolis Upper Harbor because it illustrates these potential conflicts.

The Minneapolis Upper Harbor

Minneapolis was founded on the Mississippi River. The river's kinetic energy would be harnessed to make Minneapolis the nation's early flour milling capital, and the northernmost port on the Mississippi. During the 20th Century, federal investments for navigational improvements on the Upper Mississippi provided a cheap, energy-efficient alternative for moving heavy products in and out of Minneapolis. Products associated with extractive industries like sand, gravel, limestone, cement, steel, coal, salt, fertilizer, and scrap metal.

As urban livability and environmental concerns grew during the first decade, ports became a focal point for improving freight operations: *In particular, the areas around urban ports face environmental and livability concerns because of the high concentrations of freight vehicles. Many urban ports in the United States are taking steps to reduce their impacts on neighboring communities.* [1]

in the Spring of 2015, by the time FHWA published *Delivering the Goods* article about urban freight challenges, the City of Minneapolis had already closed the Upper Harbor to barge traffic and presented plans to redevelop the harbor as a community park and performing arts center.

A study for MnDOT in 2004 found that closing the Upper Minneapolis Harbor would likely place an additional 66,000 heavy trucks traveling an estimated 1.2 million miles annually in the region. Gravel trucks moving east or northeast in the metro area were predicted to use I-94. Increases in shipping costs were estimated to exceed $4 million annually and public costs from higher road maintenance and emissions were estimated to exceed $1 million annually. *(Fruin, Fortowsky, 2004)*

PLAY 7 Evaluate the Effectiveness of Corridor Strategies

Regardless of how the corridor effort is defined or the solutions implemented ultimately corridor managers must quantify and relate how the strategies have been effective. To what degree have the actions of corridor management changed the intended performance outcomes? Which actions have resulted in intended changes, and which have not? How consistent are the outcomes of corridor management with the overall goals and objectives defined for the initiative? While corridor management regimes often utilize modeling to project scenarios and consider intended outcomes, very few corridor management regimes have consistently tracked performance over time or offered mechanisms for correcting course if impacts fail to align with intentions.

Ex-Ante, Ex-Post, and Benchmarking Approaches

The Latin term “Ex Post” means “after the event” and “Ex Ante” means before the event. These terms are instructive for understanding different ways of quantifying expected or observed corridor performance. When quantifying the impacts of corridor management, it is helpful to consider (1) intended and likely impacts based on modeling different strategies when forming a strategy (ex-ante), (2) defining specific intervals at which to apply retrospective analysis on changes associated with management actions (ex-post) and to track overall conditions as they develop in the present time (benchmarking).[27] Figure 16 demonstrates how the three types of measures can be used in corridor management strategies to assess a range of potential impacts when considering

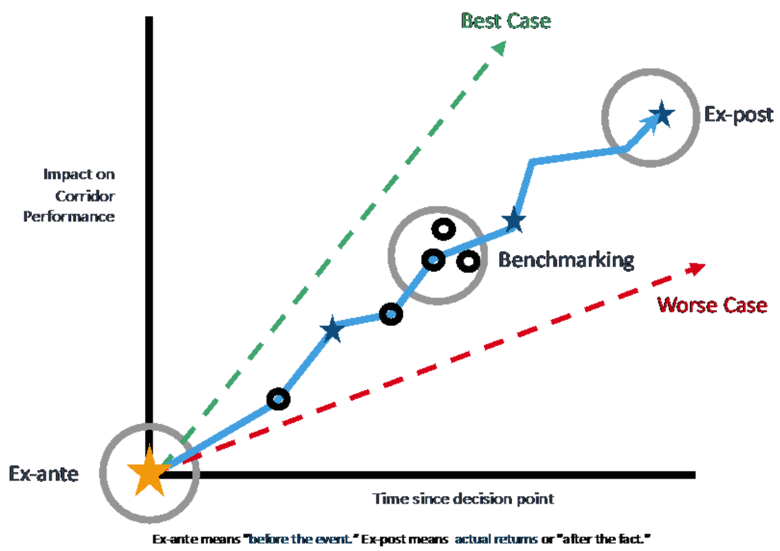

Figure 16: Ex-ante, Ex-post and Benchmarking Approaches

[27] Steven A. Smith and Transcore, “NCHRP Report 435, Guidebook for Transportation Corridor Studies: A Process for Effective Decision-Making,” 1999, https://onlinepubs.trb.org/Onlinepubs/nchrp/nchrp_rpt_435.pdf; Marek Bauer and Andrzej Szarata, “The Methodology of Urban Transport Corridors Evaluation,” 2015 International Conference on Models and Technologies for Intelligent Transportation Systems (MT-ITS), June 2015, https://doi.org/10.1109/mtits.2015.7223285; Abhishek Bhargava, Samuel Labi, and Kumares C. Sinha, “JOINT TRANSPORTATION RESEARCH PROGRAM Final Report, Development of a Framework for Ex Post Facto Evaluation of Highway Project Costs in Indiana,” March 2010, https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=2622&context=jtrp; “Welcome to EconWorks,” EconWorks Improved Economic Insight, accessed October 26, 2021, https://planningtools.transportation.org/13/econworks.html; Organization for Economic Cooperation and Development, “Benchmarking Intermodal Freight Transport,” 2002, https://doi.org/10.1787/9789264175129-en.

different elements (or scenarios) for managing corridors. When modeling impacts at the decision point, there is a rich body of research supporting scenario planning methods to forecast impact variables that may be practical to observe, calibrate and project (APP 2.7, Table 3).[28] However, these indicators may be more difficult to benchmark or monitor through the corridor management process.

The body of case research undertaken in 2020 and 2021 (APP 3.9.3) demonstrates that while ex-post methods are quite common in corridor management efforts, such evaluations often simply report a time series of performance indicators, and do not have consistent methods for associating specific outcomes with specific corridor improvement actions. Ex-ante and benchmarking are found to be less common concerning quantifying impacts of corridor management. Table 9 below offers practical guidance on key steps to arrive at ex-ante, ex-post, and benchmarking measurement of corridor outcomes.

Table 9: Ex-ante, Ex-post, and Benchmarking

Measurement Type	When to Apply	How to Apply	What to Expect
Ex Ante (Forecasting)	In initial development of corridor strategy, or when updating corridor strategy through scenario planning.	Use travel demand models, economic impact models, and predictive analytics to estimate marginal effects of corridor management actions.	Clear and quantitative expectation of intended management outcome, assuming all other factors in the corridor environment remain equal. Results will fall out of date as underlying basis of assumptions (population, technology, economy) change.
Benchmarking (Current Conditions)	Establish annual or semi-annual cycle for reporting key outcomes and drivers.	Track year over year factors and outcomes in relation to year over year management activities.	Results will not isolate outcomes specifically caused by corridor management actions. Results will show if and how the assumptions of original modeling (population, technology, economy) are changing to evaluate currency of strategy and overall changes in performance.
Ex-Post (Retrospective /Looking Back)	Establish annual or multi-year cycle for retrospective assessment linking improvement actions to outcomes	Create ratios of intended outcome metrics per improvement action. (Speed change per unit of capacity improvement) controlling for changes that are not sensitive to corridor management.	Available data and difficulty controlling for outside factors will pose challenges. Seek a small and easily measurable set of measures for indicators and improvement actions to evaluate.

[28] Nathan Higgins et al., "NCHRP 08-36/Task 145," *Scenario Planning LITE, Guidance for Scenario Planning*, March 2019, https://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP08-36Task145/NCHRP_08_36_145_FINAL_Report.pdf.

Accounting for Wider Impacts and Context

As concerns of social equity, urban development, and economic context are integral to the success of corridor management, it is essential to both diagnose and evaluate corridor management strategies using a host of land-use, social, and economic criteria. The review of corridor management efforts observed in 2020 and 2021 finds that the vast majority of corridor efforts are limited to using indicators focusing on speed, throughput, and capacity (APP 2.7, Table 3). This propensity can also be found in a review of case records in the Corridor Innovation Database (APP 9). However, corridor managers have access to a growing catalog of innovative methods for considering how changes in land-use, socio-economic conditions, and human context can both drive and result from corridor management actions. Table 10 shows a menu of innovative methodologies available for diagnosing corridor needs and evaluating scenarios with a much wider range of factors than the speed, safety, and capacity criteria that have characterized past corridor management efforts.

Table 10: New and Innovative Methods for Quantifying Corridor Management Impacts
(See Appendix 5 for instructions and Guidance)

Next Generation Corridor Impact Measurement Technique	Key Features & Applications	Location in Playbook
TOSTADA	A Geo-Database methodology and tool for assessing all of the infrastructure needs of a corridor across jurisdictions and programs through a shared data platform.	APP 5.3
Master Architecture Assessment	A standard methodology for quantifying the capacity of a wider supporting grid/connectivity architecture of a corridorfor future build-out to guide right of way preservation, partnerships with land-use agencies, and corridor projects.	APP 5.4
7D Freight Supply & Demand Assessment	A proposed process and methodology for utilizing widelyavailable data, GIS tools, and performance methods to benchmark freight infrastructure supply and demand in inter-city or urban environments.	APP 5.5
7D Built Environment	A standard methodology for identifying the extent of a corridor's influence on land-use, transit, built environment, and the efficiency of travel in affected communities to define corridor management efforts.	APP 5.6
Technology Profiling	A practical self-assessment for corridor managers to assess the technology requirements and utilization of their corridor and set objectives for integrating emerging technologies.	APP 5.7
Walkability Profiling	A GIS-based standard methodology for quantifying andllustrating the sensitivity of the bicycle and pedestrianenvironment as affected by corridor investments and associated land-use strategies, for both diagnostic and scenario planning purposes.	APP 5.8
7D Scenario Explorer	A regression-based calculator (derived from the University ofUtah's national data set) to quantify marginal effects that changes in land-use, infrastructure capacity, or other variables can have on traditional measures of corridor performance (speed, safety, VMT, and delay); for testing integrated land-use and transportation or transit scenarios.	APP 5.9

Communicating about Performance

It is essential for corridor managers to consistently and transparently communicate with stakeholders about corridor performance. Heat maps, bar charts, trend lines, strategic location maps, and indexes of corridor performance provide corridor managers with a growing range of options for demonstrating the expected and actual results of how a corridor's impact relates to the surrounding context. Corridor management dashboards are an increasingly popular method for communicating corridor management impacts to a wide range of audiences.

Using Maps to Demonstrate Corridor Relationships: While maps used in corridor management have often been used to simply demonstrate bottlenecks, level of service (LOS), or safety hot-spots, a new generation of corridor studies can take advantage of the land-use and municipal infrastructure knowledge of corridor management partners to show how a corridor relates to its wider context. Figure 17 below (further described in Appendix 5.4.7) shows the current grid spacing and connectivity of corridors in Atlanta in relation to different levels of ideal connectivity. This type of mapping can elevate the dialogue on corridor performance from simply a discussion about speed, safety, and capacity to a wider discussion about a corridor's place in the wider network of supporting infrastructure.

Figure 17: Use of mapping to evaluate effective grid-connectivity supporting corridors in the Atlanta Region. (See Appendix 5.4.7 for more on this method)

When land-use and economic development partners participate in corridor management, impact measurement techniques can offer meaningful insight regarding how different corridor management strategies relate to factors such as livability and walkability. Figure 18 below illustrates how a pedestrian access index (described in Appendix 5.8.7) can be used to facilitate dialogue between state and local transportation, land-use, and economic development stakeholders about how different corridor options relate to the walkability of a downtown.

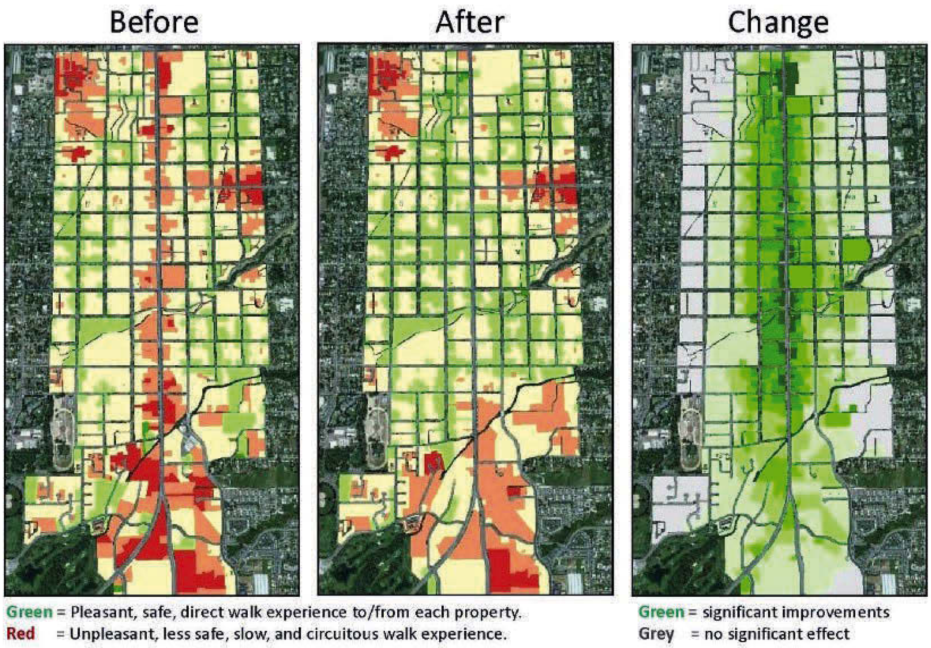

Figure 18: Heat Map Demonstrating Walkability of A Main Street Corridor in Logan, Utah (See Appendix 5.8.7 for methodology)

Figure 18 demonstrates how in the Main Street connectivity study in Logan, Utah, the *viacity* method (described in Appendix 5.8.7), enables corridor managers to (1) diagnose areas with walkability challenges related to the Main Street corridor (Before) , (2) assess the end-state of a proposed corridor improvement strategy (After) and (3) assess change or improvement in walkability (Change).

Summarizing Metrics Using Layouts: When communicating corridor impacts, it is helpful to pinpoint and summarize key statistics not only about the infrastructure but its users. A layout including key vital statistics about corridor users, their needs, and status can often "show the work" behind a corridor impact evaluation. Figure 19 (from Appendix 5.5) is an example of a business/demographic summary of a corridor profile that may be reported year over year by a corridor coalition to assess key economic indicators about a corridor's service area, dependent population, and other key aspects of business demography.

Figure 19: Demographic Layout Summarizing Users of I-80 in Iowa (See Appendix 5.5 for more on this method)

Dashboards for Different Partners: Ultimately demonstrating corridor performance on a dashboard can be extremely helpful for enabling a wide range of audiences to understand the impacts of corridor management. A key advantage of showing a range of supply and demand-side corridor improvement strategies and outcomes is showing how and why partners with the authority, resources, and information to manage a corridor can and should continue participating in the effort. Table 11 below provides instructional guidance for constructing a dashboard that can establish and maintain buy-in from key partners based on evaluation/demonstration of strategies and results. NCHRP Synthesis Visualization of Highway Performance Measures (52-16) has detailed guidance on visualization and dashboards which can be applied to corridors.

Table 11: Dashboard Elements for Relating Corridor Impact Status and Results

Key Partners	Dashboard Elements	Presentation Techniques
Business Stakeholders	• Workforce Access in Corridor • Job/Market Access in Corridor • Trend in Overall User Cost (mileage, time, environmental cost to users in dollars) • Location of Strategic Assets (facilities, firms suppliers) • Performance Hot-Spots (bottlenecks/crash points) • Cost or Economic Impact of Performance Issues	*Heat Maps* *Annotated Map Layouts* *"Red-Yellow-Green" Capacity/ Congestion Maps* *Bar Charts & Tables Showing Costs & Impacts*
Community Stakeholders	• Consumer Market Access in Corridor • Location of Strategic Destinations (Schools, Hospitals Etc.) • Performance Hot-Spots (bottlenecks/crash points)	
MPO Partners	• Inter-Local Connectivity (travel-time & mileage between centers/communities) • Key Facts About Corridor Improvement Plans • Costs and Cost-Sharing of Corridor Strategies	
Municipal Partners	• Accessibility measures to local assessed land/fiscal implications of improvements • Public Safety/Public Health/Local Police	
Elected & Appointed Leadership	• Documentation of Stakeholder Input • Documentation of Improvement Costs and Outlays • Documentation of Alternatives Considered • Funding and Financial Strategies	

Notably, the elements on a corridor dashboard do not need to all come from a single agency or one single corridor study. Part of the task of creating a meaningful corridor performance dashboard entails acquiring, processing, and synthesizing information from coalition partners (as described in Play 3: Build Durable Coalitions and Processes) into a "one-stop-shop" to benchmark or assess corridor performance. For example, a corridor coalition may be able to summarize:

From Municipal County Governments: *The value of assessed land surrounding a corridor, crime rates, substance abuse or DUI statistics, location and capabilities of key nodes such as hospitals, schools or municipal services, transit routes, paratransit service areas, air, rail, and seaport locations and access.*

From State DOTs: *Traffic counts, pavement or bridge condition and next preservation dates, crash incident locations, level of service analysis, travel time to nearby cities, truck counts, and other critical corridor performance data.*

Private Developers/ Business Groups: *Information about development plans, access requirements, parking utilization, business operations, and other information.*

By combining inputs from a wide range of partners and presenting the information with relevance to specific corridor management objectives, a corridor dashboard can provide a unique and unifying platform.

Case Example: Florida DOT District 4

Florida's Department of Transportation – District 4 has one of the most comprehensive multimodal perspectives on the corridor system of any jurisdiction in the I-95/Eastern Seaboard corridor system (Appendix 3.5.12 details this experience). Mobility Performance Measures (MMPM) help bring people together to understand and discuss how all the different plans can work together by sharing the same measures in each plan and jurisdiction within the district. The Florida DOT Central Office has developed a rich set of performance measures that define mobility for every mode, either moving people or freight, using four dimensions (quantity, quality, accessibility, and utilization). In 2019, the measures included in the FDOT Source Book are shown in Figure 20.

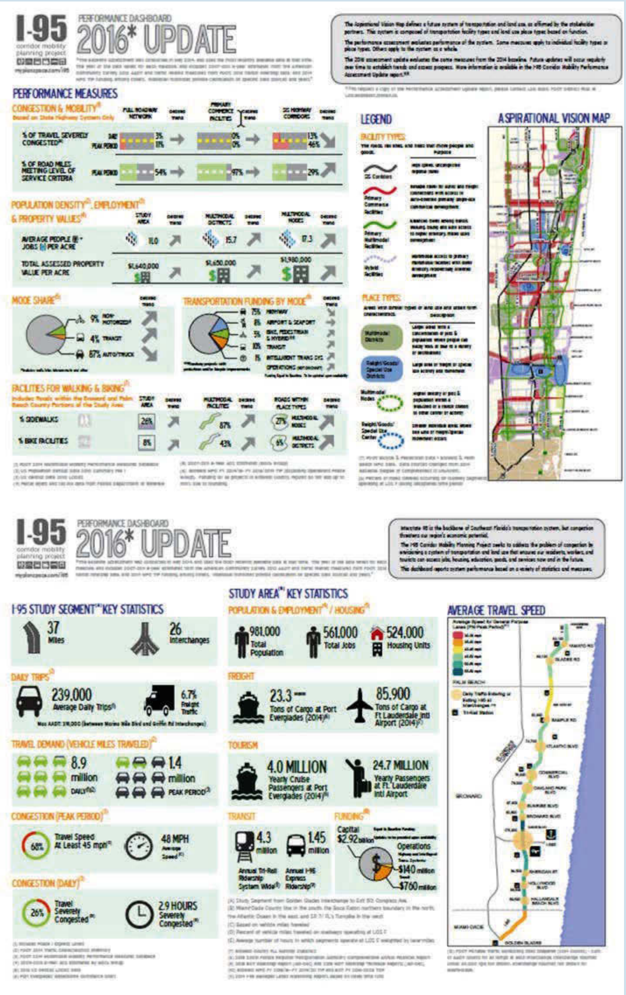

Figure 20: Florida Multimodal Performance Measures

This common set of measures is used by a number of different transportation and land-use plans in the D4 region of the cities surrounding West Palm Beach. It required many hours of discussion for the range of stakeholders to understand the measures. Travel time reliability is an excellent mobility measure, but not easily understood. Making the connection between land-use and planning is not an easy task, but the multimodal mobility performance measures provided a common framework of data that was incorporated into both the land-use and transportation plans for the region. One of the most significant benefits is that the land-use and transportation plans are now using the same data, from the same source to measure the impacts on the system from the implemented strategies and completed projects. The outcomes are measured using the same criteria. This common denominator should help improve the entire system that surrounds I-95. If local trips don't use the interstate facility, then it serves the entire region better. Appendix 3.5.12 shows infographics used by Florida DOT District 4 to demonstrate how the performance and effectiveness of the I-95 corridor strategy relate to a wide range of corridor management objectives.

The Florida District 4 case example demonstrates how a wide range of corridor performance indicators, needs, and improvement actions can be tracked and assembled into a form that supports ongoing collaboration between corridor management partners. As corridor performance dashboards become increasingly common, it should be noted that historic trend information, as well as ex-post evaluation results, could also be demonstrated on a dashboard interface similar to what Florida uses.

PLAY 8 Futureproofing a Corridor

Transportation infrastructure assets, including corridors, are long-lived assets that represent substantial resource investments to build, maintain, and operate. Given this investment, the longevity of the services provided by the corridor is a major consideration. How can a corridor coalition make investments that enable the corridor to deliver the services envisioned by the coalition for as long as possible? In short, how can a corridor coalition futureproof a corridor?

The prior plays address how an envisioned or desired state for a corridor is discussed and vetted and how strategies are proactively identified to transform the corridor from its current state to its desired state. Yet these assets operate in a dynamic environment of external forces (e.g., international trade policy and patterns, climate change, technology, fuel type and supply) that can and will affect the desired state of a corridor. The larger the geography served by the corridor or the more functions or purposes the corridor serves, the broader and more challenging the forces that could affect it.

Futureproofing a corridor involves attempting to address the uncertainty presented by these forces. It involves identifying and understanding the most significant forces that could affect a corridor and determining how best to position the corridor with projects or strategies that enable it to perform under the broadest range of potential futures. Play 5: Select Strategies and Supporting Methods/Data and Play 6: Balance Competing Uses and Sources of Value address techniques for evaluating corridors and targeting strategies based on context.

When the time horizon for a return on decisions is short, forecasting works quite well. Forecasting is based on historical data and projects forward one potential future, often with tolerances or ranges around that future much in the way the potential path of a hurricane is shown and as shown in Figure 21: Time horizon for future outcomes. The farther out from the point at which the forecast is made the less reliable the outcome.

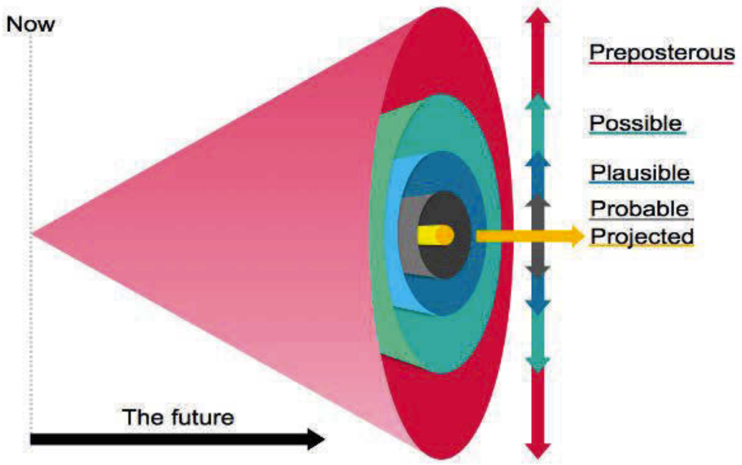

Figure 21: Time horizon for future outcomes

Scenario planning enables a longer-term approach. It is based on identifying key driving forces that could affect a desired outcome and develops multiple possible futures shaped by those forces. It integrates into potential futures the external forces that can shape the destiny of a corridor. Decisions can then be made within the contexts of the potential futures. It is a way of addressing uncertainty in long-term decisions. It is a way to try to futureproof a corridor.

The Value of Scenario Planning

The NCHRP Report 750 Foresight Series: *Strategic Issues Facing Transportation* examined global and domestic long-range, strategic issues and their implications for state departments of transportation (DOTs).[29]

The series covered goods movement, climate change, technologies, sustainability as an organizing principle, energy, socio-demographics, and preservation, maintenance, and renewal of highway infrastructure. All sought to look forward 30+ years. As a method to address the uncertainty of looking that far forward, scenario planning and variations on the scenario planning method were extensively employed. For example:

The first volume in the series, *Scenario Planning for Freight Transportation Infrastructure Investment,* contains a section on the background of the scenario planning methodology. In addition to multiple examples of scenario planning initiatives, it notes "Scenarios are methodically constructed stories about alternative futures in which today's decisions might play out." It goes on to note that for scenario planning to be effective scenarios should "make the decision makers see the future in new ways and question their unspoken assumptions." and "we must open up our minds to multiple possibilities, rather than use mental constructs that are rooted in past experience and guided by personal beliefs and preferences."[30]

The fourth volume, *Sustainability as an Organizing Principle for Transportation Agencies,* provides methods and recommendations for transportation agencies to monitor progress toward a sustainable society utilizing a Triple Bottom Line (TBL) approach that supports economic, environmental, and social objectives. The report notes, "The policy system for sustainable TBL will represent large and gradual societal culture changes over a long period. Because that system would evolve in future conditions, the research team used a scenario-planning approach to help frame the plausible conditions for transportation in a sustainable TBL society."[31] Each of these scenarios presents challenges to the implementation of transportation policies or projects that support a sustainable society. It also notes, *inter alia*, how the scenario planning effort can reveal the opportunity to pursue no or low-regrets options that bring near-term and future benefits.

The sixth volume, *The Effects of Socio-Demographics on Future Travel Demand*, looked at socio-demographic issues 30+ years into the future and how those issues could change the transportation needs, travel patterns, and expectations regarding the mobility of the U.S. population. The report found that modeling and forecasting only go so far. It found

[29] "NCHRP Foresight Report 750 Series: NCHRP," Transportation Research Board (National Academies of Sciences, Engineering, and Medicine), accessed October 28, 2021, https://www.trb.org/NCHRP/NCHRPForesightSeries.aspx?srcaud=NCHRP.

[30] Chris Caplice and Shardul Phadnis, "Strategic Issues Facing Transportation, Volume 1: Scenario Planning for Freight Transportation Infrastructure Investment," 2013, https://doi.org/10.17226/22628, p. 4.

[31] Booz Allen Hamilton, "NCHRP Report 750: Strategic Issues Facing Transportation, Volume 4: Sustainability as an Organizing Principle for Transportation Agencies," 2014, https://doi.org/10.17226/22379, p. 16.

"transportation planners often are asked to predict socio-demographic trends that will affect future demand for transportation infrastructure. The greater the degree of uncertainty associated with these trends, the more problematic the resulting decisions will be." "With knowledge of the limitations of models to produce accurate long-range forecasts, the research team focused on developing a tool *(Impacts 2050)* that would help transportation planners and decision makers apply a scenario approach for handling uncertainty."[32] That tool utilizes scenario planning methodology as its underpinning.

Decision Making within Scenario Planning

To attempt to futureproof a corridor decision-makers need to have as reasonable an understanding of what potential futures could evolve as possible. They then need to be able to evaluate decisions against those futures. Scenario planning expands the view of the potential futures and the potential environment within which the corridor will operate. Evaluating how potential projects or strategies would or could work within each future provides an opportunity for the decision-makers (perhaps coalition) to prioritize projects or strategies that provide maximum utility across the broadest range of potential futures.

Figure 22 shows how the scenario planning effort can reveal the opportunity to pursue no or low-regrets options that bring near-term and future benefits. It also highlights that decision-makers need not be simply reactive to potential futures; consideration should be given to projects or strategies that can influence the future and how the corridor could be used.

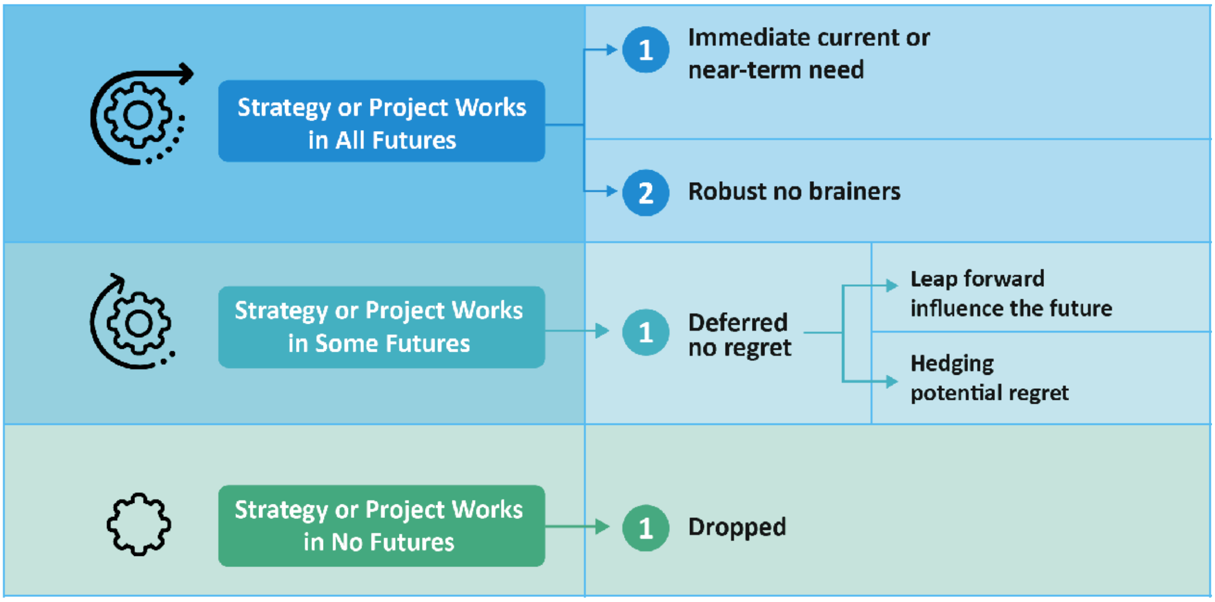

Figure 22: Scenario Planning Benefits
[This diagram is adapted from the NCHRP 750 Series]

[32] Johanna P. Zmud et al., "NCHRP Report 750: Strategic Issues Facing Transportation, Volume 6: The Effects of Socio-Demographics on Future Travel Demand," 2014, https://doi.org/10.17226/22321, p. 5-6.

Determining the Key External Drivers or Forces that Could Influence a Corridor

Scenarios are constructed around the driving challenges that often define a corridor (as shown in Play 1: Define the Corridor and Its Impact), or the assets and liabilities a corridor has relative to its context (as shown in Play 2: Take Inventory of the Corridor). The case research in Appendix 3 provides examples of corridors focused on freight movement, downtown walkability, port access, and a host of other issues. In each case example, the scenarios and performance drivers are a function of the unique requirements of the corridor environment and the balance of assets, liabilities, and value for that corridor. Much of the future uncertainty that could influence the focus of any corridor effort is driven by external forces beyond the coalition's control. These forces could include many of the topics explored in the *NCHRP 750 Foresight* series.[33] Another source for potential drivers is the Transportation Research Board's Executive Committee Reports on Critical Issues in Transportation.[34] This report, last issued in 2019, has been produced by TRB since 1976. The report defines critical issues as long-term transportation problems or questions that are currently major policy issues or are expected to be major policy issues in the next 10 to 20 years. These can provide the coalition with a potential starting place to identify key drivers.

Often the external drivers include issues not directly connected to transportation. Depending on the scale and scope of the corridor, these could include, to greater or lesser degrees, energy issues, climate change, emerging technologies, demographic trends, national and global economics, etc. A coalition's engagement in a thoughtful, wide-ranging conversation about the forces that could shape the corridor's usage and effectiveness, augmented with expertise from different disciplines, can help inform projects and strategies that can maximize the value of the effort spent in re-shaping a corridor.

Tracking the Drivers: Leading Indicators or Signposts

As scenarios are shaped around key drivers, tracking those drivers, and maintaining situational awareness of their status can provide leading indicators into which of the potential futures may be unfolding. Regularly monitoring key drivers can provide the coalition with early indicators of changes or trends as they evolve and open the possibility of deploying projects or strategies that would perform well in the scenario that is unfolding. Play 5: Select Strategies and Supporting Methods/Data offers a structure for pinpointing and monitoring trigger points in the corridor management process within the context of solution sets.

Monitoring the drivers necessitates the allocation of resources to do so over an extended period. The challenge of tracking the drivers and how it will be done can and should be considered as the scenarios are developed. Comparable to performance measures, monitoring scenario drivers that are quantitative is a matter of identifying, accessing, and utilizing a reliable data source. Monitoring scenario drivers that are qualitative can be more subjective and usually require expert interpretation. It is, however, the development and tracking of the drivers that enable the

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33 "NCHRP Foresight Report 750 Series: NCHRP," Transportation Research Board (National Academies of Sciences, Engineering, and Medicine), accessed October 28, 2021, https://www.trb.org/NCHRP/NCHRPForesightSeries.aspx?srcaud=NCHRP.

34 National Academies of Sciences, Engineering, and Medicine, "Critical Issues in Transportation 2019: Policy Snapshot," Transportation Research Board," accessed October 28, 2021, https://onlinepubs.trb.org/onlinepubs/policystudies/criticalissuesbrochure.pdf.

coalition to periodically assess and deploy relevant projects or strategies beyond those that initially work in all or most scenarios.

The identified drivers and their tracking could be woven into the benchmarking, performance, and measurement functions described in Play 7: Evaluate the Effectiveness of Corridor Strategies and tracked alongside the measures. They could be discussed when corridor coalition partners meet and then be considered for inclusion in corridor agreements.

Changing Dynamics: Revisiting the Drivers

In the document that synopsizes the *NCHRP 750 Report Series*, the Chair of the AASHTO Standing Committee on Research notes, “In today’s world, the only certainty is change—and more often than not, acceleration of change!”[35] Accordingly, revisiting the drivers that shape the scenarios and the desired state of the corridor periodically (annually or bi-annually as suggested in Play 5: Select Strategies and Supporting Methods/Data) enables the coalition to continually refresh their corridor management and be both proactive and responsive to changing dynamics. Play 6: Balance Competing Uses and Sources of Value explores how managers can use a corridor balance sheet to consistently revisit evolving sources of value for a corridor, using decision clinics with particular stakeholder classes to continually assess whether management tactics are helping or hindering a corridor’s process of evolution.

[35] “NCHRP Foresight Report 750 Series: NCHRP,” Transportation Research Board (National Academies of Sciences, Engineering, and Medicine), accessed October 28, 2021, https://www.trb.org/NCHRP/NCHRPForesightSeries.aspx?srcaud=NCHRP.

Corridor Management Playbook Appendixes

(1) Literature Review
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Appendix 1
Literature Review

1.1 Introduction

Under the often-heard adage of "doing more with less" transportation managers have frequently turned to corridor management strategies as a means of improving mobility and safety, without expanding the brick and mortar infrastructure of a corridor. In 2004, NCHRP Synthesis 337: *Cooperative Agreements for Corridor Management* explored this trend in highway practice:

> *"A growing number of transportation agencies are engaging in corridor management plans and projects to preserve the safety and mobility of major thoroughfares. Corridor management involves the application of strategies in one or more of the following areas: access management, land-use, and subdivision management, right-of-way needs and preservation, operational strategies, intergovernmental coordination, and financing of corridor management improvements."*

Currently, most corridor management efforts focus on improving the flow of goods, services, and people along roadways. However, a narrow focus on roadway travel speeds ignores important interactions between transportation corridors and the areas they serve, particularly when it comes to quality of life concerns, environmental and air quality, economic impacts, and the cost of corridor infrastructure. For instance, while Démare et al. (2017) note the existence of legal, environmental, and economic constraints on corridors when considered as a system, they posit that managing the flow of goods and providing consistent logistic services are the primary goals of when managing corridors.

Classical theory on the evolution of transport networks clearly shows the interaction between transport networks, development, and the growth of urban centers (Taaffe, Gauthier, and O'Kelly 1996). Despite this, contemporary practice has been to approach corridor projects in isolation from the growth of urban centers. This practice has led to spatially linear development patterns in some countries along major trade routes, which can end up contributing to urban congestion by concentrating traffic flows on a few links. As a result, it becomes necessary to build bypasses around the most congested cities (Kunaka & Carruthers, 2014).

A major objective of this research is to identify key attributes of effective, sustainable "form and function" corridor management, where the functional aspects of a corridor can evolve in harmony with the uses that are formed around it. In other words, we need to move away from a paradigm of defining a corridor simply by vehicle throughput, to one that includes notions of highest and best land-uses that are attractive for development. Therefore, this research will develop new performance measures that show the tradeoffs between managing corridors function while remaining attractive for development. This broader definition of corridor management offers an opportunity to coordinate transportation and land-use planning with decision-making among multiple jurisdictions and stakeholders across a range of geographic scales.

For this project, “corridors” were defined as *significant routes for the movement of people and goods* (including the placement of conventional utilities, or utilities that may transport commodities). Corridors serve users at a range of scales, from local users to national and international road, rail, and water links. The common element of corridors is that they connect demand and supply. This definition of a corridor is broader than the freight-focused definitions typically employed in the published literature. For instance, Démare et al. (2017) define corridors as links “established between a gateway port, where goods are imported, and urban areas, where the final distributors are located.” Expanding the definition to include the movement of people and goods between a wide variety of origins and destinations allows for the use of a wider set of metrics that quantify the corridor’s performance.

1.2 Quantifying Impacts

It can be ascertained from the published literature, detailed below in Table 2, that corridor management as a formal area of practice has been evolving for more than two decades, but a comprehensive review of how corridor management practices have been applied, what has worked, and how has success been measured is lacking. At the same time, the established literature on corridor management has not addressed the importance of land-uses in developing sustainable corridors. The objective of this research is to demonstrate the importance of considering land-uses when developing an overall corridor improvement strategy. How land-uses affect the sustainability and operation of corridors by exploring land-use attributes that affect the sustainability and operation of corridors will be explored.

The objective of this research is (1) to produce a framework for measuring the impacts of a more comprehensive definition of corridor management, demonstrating applicable strategies and techniques; and (2) to develop guidelines for how to implement such a framework.

1.3 State of the Practice in Corridor Management

One-hundred and forty-four corridor studies published in research journals and by public and private organizations were reviewed. The goal of this literature review is to determine how the impacts of corridor management have been assessed in the past, as well as the conceptual frameworks used by transportation agencies to select and prioritize performance measures for transportation corridors.

Multimodal Corridors Focusing on multimodal corridors also fits the traditional concepts of integrated corridor management (ICM) framework developed by the U.S. Department of Transportation. ICM refers to coordination among adjacent transportation facilities on operations and infrastructure investments to create an interconnected system capable of cross-network travel. Zhou, Mahmassani & Zhang (2008) note that, by taking advantage of advanced transportation analysis tools to estimate and predict network conditions and to analyze network performance, as well as communication and sensing technologies that provide an integrated, system-level perspective, ICM can improve travel times, delays, fuel consumption and emissions, and the reliability and predictability of travel within corridors.

1.4 Big Data and Optimization in Corridor Management

One of the biggest advances in understanding transportation corridor operations in the past decade has been the advent of real-time or near real-time GPS vehicle tracking information. The trucking industry was one of the early adopters of in-vehicle GPS tracking systems. While trucking company customers appreciated the information GPS systems could supply about shipment location and status in real-time, trucking companies also saw a new data source that could be used for improving operational efficiency.

Optimization is an often-misused term of reference for any process used to identify a "best" solution. However, in the context of network simulation and company problem-solving, optimization is more accurately described as a mathematical approach to finding the best solution using linear programming applied to big data. Private sector freight service providers and shippers have used mathematical optimization for decades to improve efficiency and reduce costs. Examples include the Class I railroads who used optimization models in the wake of deregulation to rationalize their networks and improve profitability. Trucking fleets use network optimization to determine where terminals should be located based on customer demand and operating costs associated with fuel and driver wages. Shippers use optimization to make facility location decisions that result in the lowest cost supply chain network. In a recent iteration of an annual survey of third-party logistics (3PL) services conducted by Penn State University, 39 percent of shippers indicated that network modeling and optimization were capabilities they looked for in 3PL providers, and 62 percent of responding 3PLs said they offer those capabilities.

Optimization modeling has only recently appeared as a tool in public sector decision-making. One area of public sector planning where optimization has gained prominence is emergency evacuation and emergency response planning. For example, in 2008 researchers at the University of Maryland developed a corridor-based emergency evacuation model for Washington D.C. The model divided the D.C. area into evacuation corridors and applies optimization and simulation to generate traffic signal timing and route strategies that result in the most efficient means to evacuate the urban area.

Optimization is also being used by some transportation agencies to examine freight issues. The Iowa Department of Transportation and Nebraska Department of Transportation have both developed optimization models to evaluate their multimodal freight networks. The models evaluate key shipping lanes (i.e. corridors) and identify the most cost-effective means of moving goods in those corridors. In another corridor-based example, the Texas Department of Transportation is currently developing a truck parking model for the I-10 Corridor that will examine the optimal location of truck parking facilities, based on truck GPS trip data and hours-of-service regulations.

1.4.1 Traditional Corridor Management Performance Measures

Measures of congestion, reliability, pavement condition, safety, and other long-range planning measures are the most common measures used to quantify the performance of transportation corridors.

A total of 129 of the sources reviewed for this project include the keywords congestion, delay, or "traffic jam." The World Bank's *Trade and Transport Corridor Management Toolkit* (Kunaka & Carruthers, 2014), for instance, states that estimating the potential volume of traffic between origins and destinations and identifying bottlenecks and choke-points are the first priorities for agencies planning corridor improvements.

The high number of studies dedicated to improving methods of calculating and predicting travel times along a corridor demonstrates the importance placed on reducing congestion and delay. Eighty studies devoted to developing or improving models for predicting traffic congestion were identified. Various studies applied gravity models, dynamic traffic assignment models, utility models, simulation models, and other methods of predicting traffic.

Table 1. Metrics used to quantify corridor performance

Category	Metrics	Reference
Operational performance	Transport service frequency	Wiegmans & Janic (2019)
	Size of deployed vehicle fleet	Wiegmans & Janic (2019)
	Technical productivity	Janic (2016), Wiegmans & Janic (2019)
Traffic Incident Management	Incident Responses (Number, type)	Abou-Senna et al. (2018)
	Incident (Duration, Response Time)	Abou-Senna et al. (2018)
	Average Incident Clearance Time	Abou-Senna et al. (2018)
	Number of Lanes Blocked, Closed	Abou-Senna et al. (2018)
	Rate/number of collisions	Abou-Senna et al. (2018)
	Rate/number of collisions (fatalities, injuries)	Abou-Senna et al. (2018)
Travel Time Reliability	Travel-Time Index	Abou-Senna et al. (2018), Mailer (2016)
	Planning Time Index	Pandey & Juri (2018), Abou-Senna et al. (2018)
	Buffer Time Index	Pandey & Juri (2018), Abou-Senna et al. (2018)
	On-time Performance	Pandey & Juri (2018), Abou-Senna et al. (2018)
Travel Time	Average Travel-time	Abou-Senna et al. (2018), Lee et al. (2019)
	Average Speed	Abou-Senna et al. (2018), Lee et al. (2019), Mbiydzenyuy (2018)
	Variance of Speed	Mbiydzenyuy (2018)
	Event Travel Time	Abou-Senna et al. (2018)

Category	Metrics	Reference
	Work zone speed reduction	Abou-Senna et al. (2018)
	Work Zone Lane Shifts	Abou-Senna et al. (2018)
	Transit time and Variation	Mbiydzenyuy (2018)
	Evacuation Time	Abou-Senna et al. (2018)
Multimodal approach	Light Passenger Vehicles (LPV)	Fernandes et al. (2017), Abou-Senna et al. (2018)
	Heavy Duty Vehicles (HDV)	Fernandes et al. (2017), Abou-Senna et al. (2018)
	Freight volume	Abou-Senna et al. (2018), Mbiydzenyuy (2018)
	Travel-times on key freight corridors	Abou-Senna et al. (2018)
	Transit Delay changes (%)	Abou-Senna et al. (2018), Lee et al. (2019)
	On-time Performance	Abou-Senna et al. (2018)
Transportation Demand Management	Congestion (Spatial, Temporal)	Abou-Senna et al. (2018), Mbiydzenyuy (2018)
	Volume per hour (Vehicle, person)	Abou-Senna et al. (2018)
	Vehicle class Distribution on Network	Abou-Senna et al. (2018), Mbiydzenyuy (2018)
	Delay (Event, Work Zone)	Abou-Senna et al. (2018)
Active Transportation Management (ATM) (ramp metering control)	Average trip travel time	Lee et al. (2019)
	Average trip delay	Lee et al. (2019)
Economic performance	Economic Impact Factor (EIF)	Dzumbira et al. (2017)
	Secondary Corridor Impact Factor (SCIF)	Dzumbira et al. (2017)
	Average costs of freight shipment(s)	Wiegmans & Janic (2019)
	Vehicle Miles Traveled	Abou-Senna et al. (2018)

Category	Metrics	Reference
Environmental and social performance	Vehicle Emissions (CO2, CO, NOx, VOC)	Abou-Senna et al. (2018), Wiegmans & Janic (2019)
	Transit Vehicle Fuel Efficiency	Abou-Senna et al. (2018)
	Consumption (energy, fuel)	Wiegmans & Janic (2019)
	Cost of incident(accident)	Janic & Vleugel (2012), Wiegmans & Janic (2019)
Customer satisfaction	% of Pop. satisfied with travel conditions	Abou-Senna et al. (2018)
	Number, type of hits (app data, web)	Abou-Senna et al. (2018), Mbiydzenyuy (2018)
	Compliment Rate	Abou-Senna et al. (2018)
	Complaint Rate	Abou-Senna et al. (2018), Mbiydzenyuy (2018)
Corridor Infrastructure	Geographical Information	Lee et al. (2019)
	Chain length	Wiegmans & Janic (2019)
	Route length	Wiegmans & Janic (2019)
	Accessibility	Wiegmans & Janic (2019)
	Area coverage	Wiegmans & Janic (2019), Mbiydzenyuy (2018)
	Infrastructure density	Wiegmans & Janic (2019), Lee et al. (2019), Mbiydzenyuy (2018)
Dynamic Traffic Assignment (DTA)	DTA	Van Den Berg et al. (2004), Lee et al. (2019), Fernandes et al. (2017)
	Integrated DTA-RM	Lee et al. (2019),
	Mesoscopic DTA	Zhu et al. (2018)
	Integrated AgBM-DTA	Zhu et al. (2018), Lee et al. (2019)
	O-D matrices	Lee et al. (2019), Fernandes et al. (2017)

Table 2. Selected bibliography of most relevant sources

Topic	Subtopic	Author(s)	Title	Keywords	Purpose	Method	Results
Travel Demand Modeling	Google	(Sana, Castiglione, Cooper, & Tischler, 2017)	Using Google's aggregated and anonymized trip data to support freeway corridor management planning in San Francisco, California.		This paper describes a new passively collected O-D data source—Google's aggregated and anonymized trip (AAT) data—obtained under Google's Better Cities program. Aggregate hourly flow matrices for 85 districts covering California's nine-county Bay Area specific to four freeway segments in San Francisco were obtained. Because AAT data account for only a sample of travelers, Google pro- vides relative flows rather than absolute counts.	Linear regression models.	Comparison of these facility-specific O-D matrices to select link O-D matrices from a regional travel demand model show that there is a higher correlation in terms of productions at origin districts and attractions at destination districts than at the O-D flow level.
Travel Demand Modeling	Mobile phone data	(Shi & Zhu, 2019)	Analysis of trip generation rates in residential commuting based on mobile phone signaling data.	Trip rate, signaling data, commuting trip, trip generation, trip production, trip attraction.	Mobile phone signaling data are first processed to extract information such as the trip volume and spatial distribution from the starting point to the termination point. This information is then used to identify the residential and employment locations of users.	Multiple Thiessen polygons based on cell towers are aggregated into Traffic Analysis Zones (TAZs); Multiple stepwise regression.	This paper suggests that as information and data sharing continue, mobile phone signaling data will become increasingly important for use in future trip rate research.
Travel Demand Modeling	Mobile phone data	(Steenbruggen, Borzacchiello, Nijkamp, & Scholten, 2013)	Mobile phone data from GSM networks for traffic parameter and urban spatial pattern assessment: A review of applications and opportunities	GSM network; Mobile phones; Traffic management; Transportation applications	The aim of this paper is to provide a systematic overview of the main studies and projects addressing the use of data derived from mobile phone networks to obtain location and traffic estimations of individuals, as a starting point for further research on incident and traffic management.	qualitative	
Travel Demand Modeling	Wi-Fi signal	(Ding et al., 2019)	Evaluation of a Wi-Fi signal-based system for freeway traffic states monitoring; An exploratory field test.	Internet of things (IoT); Performance evaluation; Speed detection; Traffic characteristics monitoring; Wi-Fi signal detector.	This paper explores a supplementary and novel data source, Wi-Fi signal data, to extract traffic information through a well-designed system. An IoT (Internet of Things)-based Wi-Fi signal detector consisting of a solar power module, high capacity module, and IoT functioning module was constructed to collect Wi-Fi signal data.	Proposed Filtering and Mining Algorithm; Field test.	The comparison results with loop data indicated that traffic speed obtained from the system was consistent with that collected from loop detectors. -The evaluation confirmed the feasibility of applying Wi-Fi signal data to acquisition of traffic information, indicating that Wi-Fi signal data could be used as a supplementary data source for monitoring real-time traffic states.

Topic	Subtopic	Author(s)	Title	Keywords	Purpose	Method	Results
Economy Impact	Project evaluation	(Prodan & Teixeira, 2018)	Incorporating Economic Assessment into Capacity Allocation and Infrastructure Charging Policies for Vertically Separated Railways.		This work proposes a methodological framework for evaluating impacts of capacity allocation and infrastructure pricing policies on society by applying a set of project evaluation guidelines that are normally used for new infrastructure projects to a set of capacity allocation and pricing policies.	Cost–benefit analysis; Case study	The results of this evaluation show the total impact of a particular policy on each player, including society. External costs are also considered in this evaluation. This approach can be used by decision-makers to make more informed decisions when setting infrastructure charging and capacity allocation policy.
Land-use	Transportation, land-use integration policy	(Rooney, Savage, Rue, Toth, & Venner, 2010)	Corridor Approaches to Integrating Transportation and		The objective of this research is to identify and explore successful innovations in integrating transportation and land-use planning for transportation corridors, with a focus on practices that could be transferred to other locations.	Case study	Simultaneous land-use and transportation planning, with both sets of agencies at the table creating and exploring solutions together.
Land-use	Change prediction	(Bardhan, 2013)	Simulation of Land-use Consequences of Urban Corridor in Kolkata: An Integrated Spatial and Expert System Model	Urban corridor; analytical hierarchical process; internalizing of benefits; land-use transformation; multi-variate grid analysis; property values; transition probability index (TPI).	This study examines land-use transitions due to development of transport corridor using expert judgment analytic hierarchy process (AHP) for measuring priority ranking of a particular land-use to transit to other use, along the second Vivekananda Bridge-Belghoria Expressway(2VBBE) running through a relatively depressed urban fringe of Kolkata, India.	AHP; -spatial model-Multivariate Grid Analysis (MVGA).	MVGA cumulatively uses property values, accessibility, environmental, and demographic factors to project the proposed land-use structure for 2020. It spatially predicts land-uses that might undergo incredible changes due to the facility development.
Land-use		(Chen et al., 2012)	A GIS-Based Model for Land-use and Transit-Integrated Corridor Optimization.		Based on the conception of Transit-Oriented Development (TOD) and sustainable development, this study aims to establish a GIS-based model for integrating land-use development along transit corridors. The purpose of the model is to optimize and integrate the development of land-use and public transit.	TOPSIS (technique for order preference by similarity to ideal solution) approach.	
Managemen t	Air quality; Emissions	(Choudhary & Gokhale, 2019)	Evaluation of emission reduction benefits of traffic flow management and technology upgrades in a congested urban traffic corridor.	Auto-rickshaw; CNG; Emissions mitigation; Traffic flow.	The main objectives are: (1) to characterize real-world operating kinetics of gasoline-fueled passenger cars and auto-rickshaws, (2) to evaluate the models, and (3) to reduce emission from three what-if scenarios—upgrade of Euro emission standards from III		The results show that the upgrade from Euro-III to Euro-VI emission standards for passenger cars could reduce up to 83–90% of CO, 86–92% of HC, 83–84% of CO2 during peak hours, and 77% of NOx emissions during off-peak hours. The change of fuel from gasoline to CNG for auto-

Topic	Subtopic	Author(s)	Title	Keywords	Purpose	Method	Results
					to VI, shift to CNG from gasoline and regulate the number of buses halts and its duration.		rickshaw could reduce up to 89% of HC and CO, 32–36% of CO2 during peak hours, and 23–56% of NOx emissions during off-peak hours. And, by regulating the frequency of buses, emissions of CO2, CO, and HC from both passenger car and auto-rickshaw reduced up to 40–66% during peak hours and NOx up to 40% during off-peak hours. The results, thus, showed that traffic flow management can bring significant emission reductions.
Managemen t	Congestion	Bélisle, Torres, Volet, Hale, & Avr, 2019)	Evaluating the HERO Ramp-Metering Algorithm with San Diego's Integrated Corridor Management System Model.		''Alternative Designs to Alleviate Freeway Bottlenecks at Merge/Diverge and Weaving Areas'' aims at evaluating six different methods to mitigate merge impacts. Ramp-metering algorithms were tested.	Ramp-metering algorithms; heuristic Ramp metering coordination (HERO), Asservissement Line´aire d'entre´e sur Autoroute (ALINEA), and San Diego Ramp Meter System (SDRMS).	HERO was found to outperform all the other algorithms: gains of 1.5% over ALINEA and 4% over do-nothing on the mainline average travel time, and gains of 0.5% over ALINEA and 1.5% over do- nothing for the average weighted harmonic speed on all mainline and ramp sections.
Managemen t	Congestion	(Hashemi & Abdelghany, 2018)	End-to-End Deep Learning Methodology for Real-Time Traffic Network Management.		Identify the time-varying traffic congestion pattern in the network and recommend integrated traffic management schemes to reduce this congestion.	End-to-end deep learning (E2EDL).	The E2EDL system achieves travel time savings comparable to those recorded for an optimization-based traffic management system.
Managemen t	Congestion	(Hashemi & Abdelghany, 2016)	Real-time traffic network state estimation and prediction with decision support capabilities: Application to integrated corridor management.	Traffic network management; State estimation and prediction; Dynamic traffic assignment; Genetic algorithms.	This paper presents a real-time traffic network state estimation and prediction system with built-in decision support capabilities for traffic network management.	Simulation-based case study.	The ability of the system to improve the overall network performance during hypothetical incident scenarios.
Managemen t	Congestion	(Hashemi & Abdelghany, 2015)	Integrated Method for Online Calibration of Real-		This paper presents an integrated method for online calibration of real-time traffic network simulation models. The method integrates a time-dependent demand	time-dependent demand adjustment module; link-	The online calibration method is effective in enhancing the model's consistency in the different operational conditions.

Topic	Subtopic	Author(s)	Title	Keywords	Purpose	Method	Results
			Time Traffic Network Management Systems.		adjustment module and a link-based traffic flow propagation model calibration module.	based traffic flow propagation model.	
Managemen t	Congestion	(Zhang et al., 2015)	Implementation of Real-Time Offset-Tuning Algorithm for Integrated Corridor Management.		Proactive, real-time offset-tuning algorithm to explicitly incorporate diversion traffic and patterns into ICM strategies.	Offset-Tuning Algorithm.	The statistical analysis proved that the average control delay for both the direction of the diversion and the opposite direction, for all intersections, decreased by 5.6%, with a lower control delay at the 95% confidence interval. The diversion contributed to a gain of 9.22 mph or 18.96% in average speed on the freeway.
Managemen t	Congestion	(H. X. Liu & Jabari, 2008)	Evaluation of corridor traffic management and planning strategies that use microsimulation: A case study		The California SR-41 corridor simulation project is presented as a case study of how to utilize microscopic traffic simulation for planning purposes	Origin–destination (O-D) matrix calibration; Peak spreading for long-term testing.	O-D calibration process: The model reproduces count and travel-time information collected from the field. Peak spreading: performance improvements in the models and overcome network gridlock issues common to such applications.
Managemen t	Congestion	(Mahmassani & Jayakrishnan, 1991)	System Performance and user Response Under Real-Time Information In a Congested Traffic Corridor.		Analyze the effect of in-vehicle real-time information strategies on the performance of a congested traffic commuting corridor.	Traffic simulation with a user behavior component.	
Managemen t	Congestion	(Asare & Smith, 2014)	Evaluation Framework for Rigorous Exploration of Potential Benefits of Integrated Corridor Management.		This study proposed an ICM evaluation framework that was based on which strategies critical to congestion mitigation in a corridor could be identified.	ICM evaluation framework.	An average flow increment in the corridor of 6,860 persons per hour (137.8%) was experienced during incident conditions com-pared with 3,286 persons per hour (114.4%) for non-incident conditions. Improvements were also observed in average travel times and vehicle emissions.
Managemen t	Congestion	(Yang, Cheng, & Chang, 2018)	Integration of adaptive signal control and freeway off-ramp priority control for commuting corridors.	Adaptive signal control; Off-ramp priority control; Green extension; Dynamic signal progression.	This study develops an integrated control system that includes three primary functions: off-ramp queue estimation, arterial adaptive signal operations, and freeway off-ramp priority control.	Simulation model.	The overall network performance can indeed be improved under the proposed control system, compared with other operational strategies. Further analyses of freeway time-dependent travel time distribution also evidence the effectiveness of the proposed system in preventing off-ramp queue spillover.

Topic	Subtopic	Author(s)	Title	Keywords	Purpose	Method	Results
Managemen t	Safety	(Effati, Thill, & Shabani, 2015)	Geospatial and machine learning techniques for wicked social science problems: analysis of crash severity on a regional highway corridor	Crash severity; Machine learning; Road safety; Spatial analysis; Spatial dependence; Spatial heterogeneity; Wicked problems.	Using machine learning methods to unravel the complexity of traffic crash severity on highway corridors.	Support vector machine (SVM); Coactive neuro-fuzzy inference system (CANFIS) algorithms.	The SVM model outperforms CANFIS by a notable margin. The combined use of spatial analysis and artificial intelligence is effective at identifying leading factors of crash severity, while explicitly accounting for spatial dependence and spatial heterogeneity effects.
Managemen t	Safety	(Yu, Feng, Liu, Ma, & Yang, 2019)	Corridor-level cooperative trajectory optimization with connected and automated vehicles.	Connected and automated vehicle; Trajectory optimization and coordination Corridor; Mixed-integer linear programming.	Proposes a mixed-integer linear programming (MILP) model to cooperatively optimize the trajectories of C-AVs along a corridor for system optimality. The car-following and lane-changing behaviors of each vehicle along the entire path are optimized together.	-mixed-integer linear programming (MILP) model.	The analysis of the impacts of the safety time gap for collision avoidance within intersection areas indicates that the proposed model can greatly increase the intersection capacity CAV-based control outperforms coordinated fixed-time control.
Managemen t	Stakeholder, Decision making	(Kurapati, Kourounioti, Lukosch, Tavasszy, & Verbraeck, 2018)	The role of Situation Awareness in Synchro-modality Corridor Management: A simulation gaming perspective.	Corridor management; Simulation games; Situational Awareness; Synchro modality; Transport.	The aim of this paper is to present the idea and the design of a game developed to increase the SA of transport and encourage infrastructure managers to make suitable decisions towards improved performance within a synchro modal transport network.	The modal manager game, "Microgame."	The different levels of situational awareness the players develop during the game are related to the distinct levels of play options in the game.
Managemen t	Cooperative agreements between two or more entities that address land-use and transportation linkages.	(K. Williams, 2004)	NCHRP Synthesis 337: Cooperative Agreements for Corridor Management.	Cooperative Agreements; Corridor Management; Land-use; Transportation Linkages.	The synthesis examines the current state of practice in developing and implementing cooperative agreements for corridor management, elements of such agreements, and successful practices or lessons learned.	Three basic methods were used to develop the synthesis: (1) a survey of each state transportation agency in the United States and each provincial transportation agency in Canada, (2) a review of the published	A common theme in developing effective agreements is that tough issues need to be resolved through direct involvement of affected parties. Readiness to compromise, treating all participants as equal partners, and keeping all parties to the agreement apprised of substantive developments throughout the process were other suggestions from respondents and the literature. A related theme in current practice is the importance of establishing a shared vision of the corridor and for each party to look at the corridor as a whole—not just from within or outside of the right-of-way. The willingness of each party to work toward a common vision and to compromise for mutual benefit can form the basis of a lasting and effective agreement on corridor management.

Topic	Subtopic	Author(s)	Title	Keywords	Purpose	Method	Results
						literature and government documents, and (3) follow-up questions with selected individuals.	
Management	Intermodal Corridor Management	(J. Wallace, B. Hoeft, J. Lambert, K. Martin; N. Spiller; S. Takigawa; L. Weiskopf; B. Smith, 2016)	NCHRP 20-68A - 1402 - Successful Inter-Modal Corridor Management Practices	Collaboration; Economy; Linkages; Modal; Performance Parameters; Sustainable Transportation; Investments; Corridor Vision and Goals: Systems Approach; Funding.	To produce practical guidance and examples for state departments of transportation and metropolitan planning organizations seeking opportunities to coordinate investments in multiple modal transportation networks within a corridor to maximize capacity and capitalize on investments creating synergies between modes.	Peer-exchange type of workshops to gather information on best practices and enable interaction between practitioners themselves.	This project found no “silver bullets” when it comes to examples of successful, fully developed intermodal corridor management. However, many areas of the country are putting the pieces together to provide best practices that others can use as they move forward.
Management	Environmental Corridor Management	(M. Venner, A. Santalucia, 2010)	NCHRP 25-25(63) - Environmental Corridor Management	Resource Use and Recycling; Water Quality; Roadside Environmental Management; Energy.	Develop a framework for conducting and documenting environmental management activities by corridor, focusing on the core maintenance practices of roadside management and the primary areas of attention for environmental performance measurement. This report also explores how DOTs can use data and decision-support systems to implement, track, and report on corridor-based environmental management.	Survey of DOTs and presentation and interviews vis focus groups.	Framework
Performance Management	Air quality; Emissions	(Fernandes, Coelho, & Rouphail, 2017)	Assessing the impact of closely spaced intersections on traffic operations and pollutant emissions on a corridor level	Intersections Multi-objective optimization Micro-scale modeling Spacing	An understanding of the impacts on traffic regarding highly congested closely spaced intersections has not been fully addressed. Accordingly, how these specific segments affect corridor performance as a whole	Traffic simulation model (VISSIM); emissions methodology (Vehicle Specific Power – VSP).	The analysis showed that the roundabout could achieve lower queue length (64%) and emissions (16–27%, depending on the pollutant) than the traffic light. The results also suggested that 200 m of spacing using the best traffic control would provide a moderate advantage in traffic operations and emissions as compared with the existing spacing.
Quantify impacts	Economic	(Dzumbira, Geyer Jr., & Geyer, 2017)	Measuring the spatial economic impact of the	Development corridor; development axis;	This study empirically establishes the influence of nodes along the MDC and ascertains the statistical significance of the	standard statistical analyses;	

Topic	Subtopic	Author(s)	Title	Keywords	Purpose	Method	Results
			Maputo Development Corridor.	development node; growth pole; spatial economic impact; economic impact.	impact of the corridor over distance away from its spine.	multivariate regression analysis.	
Quantify impacts	Land-use; Travel behavior	(Zhu, Xiong, Chen, He, & Zhang, 2018)	Integrating mesoscopic dynamic traffic assignment with agent-based travel behavior models for cumulative land development impact analysis.	Agent-based behavior model Transportation planning Dynamic traffic assignment Simulation-based optimization.	This study integrates DTA with the agent-based positive travel behavior model to estimate the transportation impact under cumulative land developments.	Agent-based behavior mode.	The integration with the positive model enhances the behavior realism of DTA, resulting in the capability to capture dynamic travel behavior pattern changes.
Quantify impacts	Sustainability; Programming; Project selection	(Oswald & McNeil, 2010)	Rating Sustainability: Transportation Investments in Urban Corridors as a Case Study.	Sustainable development; Transportation corridors; Ratings; Decision-making.	This research **develops a methodology for rating systems** and applies the system to transportation investments, specifically urban corridors.	AHP; MAUT.	Sustainable corridor rating system (SCRS) is intended to alter the behavior of transportation practitioners and induce sustainable transportation practices by defining a methodology for developing green rating systems. The methodology defined in this research can be applied universally to the development of green rating systems similar to SCRS.
Quantify impacts		(Lee, Xiong, Zhu, Zhou, & Zhang, 2019)	Analyzing Simulation-Based Active Traffic Management Impact on a Large-Scale Regional Network		This study integrates a mesoscopic dynamic traffic assignment simulation model with an existing traffic-responsive ramp metering strategy.		The results indicate that ramp metering is beneficial even under non-recurrent traffic conditions at multiple spatial resolutions.
Quantify impacts		(X. Liu, Zhang, Kwan, Wang, & Kemper, 2013)	Simulation-Based, Scenario-Driven Integrated Corridor Management Strategy Analysis.		The analysis aimed to quantify network-wide ICM performance by empirically diverting traffic to adjacent arterials in response to incident management for freeway operations.	-VISSIM simulation model.	
Quantify Impacts	Cost-Benefit Analysis	(S. Vadali C. James Kruse, K. Kuhn, A. Goodchild, 2017)	NCHRP 38 - Guide for Conducting Benefit-Cost Analysis of Multimodal, Multijurisdictional Freight Corridor Investments	Valuation; Reliability; Resilience; Risk Analysis; Cost Benefit; Corridors; Externalities; Data; Metrics; Equity; Intergenerational Transfers; Monetization	To give decision-makers, practitioners, and stakeholders an actionable resource and a reference for multimodal freight investment benefit-cost analysis, data sources, and tools for projects of different geographic scales.	The guidelines are based on detailed literature reviews and an assessment of the state of the practice.	Guidebook

Topic	Subtopic	Author(s)	Title	Keywords	Purpose	Method	Results
Planning	The beginning and end of the statewide corridor planning (SWCP) process	(M. Meyer, J. Carr, C. Dixon, 2010, 2016)	NCHRP 661 - Guidebook on Corridor-Based Statewide Planning	Corridor Based Planning; Land-use; Urban Design; Economic Development; Freight Movement; Public Transport; Operations; Safety; Planning and Environmental Linkages; Performance Measures; Innovative Financing; Public-Private Partnerships.	To provide a template for corridor planning that will assist states in better understanding the implications of transportation decisions on mobility, communities, economic development, and environmental stewardship. The template can be a useful tool to help states program funds to meet identified needs and priorities.	To meet the project objectives, a literature review was conducted, applicable federal requirements and guidance were identified, surveys and case study. Research was undertaken to further examine the current state of the practice, effective approaches and practices used by states and MPOs were identified, and a peer review of the draft guidebook was conducted to gather feedback on its content.	Technical guidance on the activities and actions that transportation planners can follow to develop an SWCP approach to statewide transportation planning.

1.5 The 7-D Framework

A literature review documenting the impact of the 7-Ds on land-uses has also been included as well as a brief summary of how traditional corridor management practices have implicitly considered aspects of the 7-D framework.

A promising approach to assessing travel demand that has not been applied to corridor management previously is the 7-D, or "D variables" framework. In the planning and transportation literature, influences of the built environment on travel behavior have often been named with words beginning with the letter "D" — e.g., density, diversity, design, destination accessibility, and distance to transit (Ewing & Cervero, 2010). These are gross qualities of the urban environment. More than 200 studies have sought to explain household travel outcomes such as trip frequencies, mode choices, trip distances, or overall vehicle miles traveled using one or more of the D variables.

The original "three Ds," coined by Cervero and Kockelman (1997), are density, diversity, and design, followed later by destination accessibility and distance to transit (Ewing and Cervero, 2001). Demand management (primarily operationalized as parking management) is sometimes included among the Ds. Demographics are a seventh D that controls for confounding influences in travel studies. While not part of the environment, the demographic characteristics of populations can be strong predictors of both trip frequency and vehicle ownership.

Table 2 provides full definitions of the D variables and examples of how they are measured and operationalized. Note that these are rough categories, divided by ambiguous and unsettled boundaries that might change in the future. Some dimensions overlap (e.g. diversity and destination accessibility). Nonetheless, the D variables form a useful framework to understand how metropolitan-scale characteristics of the built environment can influence travel behavior on a larger scale along long-range transportation corridors that serve metropolitan areas.

There are rich studies on the built environment and travel in the research literature. A meta-analysis in 2010 found more than 200 individual studies of the built environment and travel (Ewing and Cervero, 2010). A more recent meta-regression analysis expanded this sample considerably (Stevens, 2017). The most common travel outcomes in these studies are VMT, walk trips, and transit trips. The D variables were population density and job density; diversity measured in terms of jobs– population balance and land-use entropy; design measured in terms of intersection density and street connectivity; destination accessibility measured in terms of jobs reachable within a given travel time by car and transit; and distance to transit measured directly. For all travel outcomes and D variables, the relationships proved inelastic, that is, they had absolute values of less than 1. The weighted average elasticity with the greatest absolute magnitude was 0.39, and most elasticities were much smaller. Still, the combined effect of several built environmental variables on travel could be quite large. These elasticities can be used to quantify the impact of changes in D variables in sketch planning applications. Among the Ds, destination accessibility appears to have the strongest relationship to VMT, probably followed by street network design. The relationship of distance to transit to VMT is relatively weak, and the other two D variables have relationships that vary based on the specific method of calculation and the sample selected. The combined impact of these variables on VMT could be quite large (Ewing and Cervero, 2017).

A number of studies, including Crane (1996), Cervero and Kockelman (1997), Kockelman (1997), Boarnet and Crane (2001), Cervero (2002), Zhang (2004), and Cao et al. (2009b), provide economic and behavioral explanations of why built environments might be expected to influence travel choices. The first five Ds affect the accessibility of trip productions to trip attractions, and hence the generalized cost of travel by different modes to and from different locations. This, via the consumer choice theory of travel demand (Ben-Akiva and Lerman, 1985; Domencich and McFadden, 1975), affects the utility of different travel choices. For example, destinations that are closer as a result of higher development density or greater land-use diversity may be easier to walk to than drive to. As the D values increase (except distance to transit, with an inverse relationship), the generalized cost of travel by alternative modes decreases, relative utility increases, and travelers are more likely to choose non-automobile modes.

Generalizing across this vast literature, trip frequency is primarily a function of socioeconomic characteristics of travelers and secondarily a function of the built environment; trip length is primarily a function of the built environment and secondarily of socioeconomic characteristics; and mode choice depends on both, though probably more on socioeconomics. Vehicle miles traveled (VMT) and vehicle hours traveled (VHT) also depend on both. Trip lengths are generally shorter at locations that are more accessible and have higher densities or feature mixed-uses. This is true both when comparing home-based trips from different residential neighborhoods and trips to non-home destinations in different activity centers. Destination accessibility is the dominant environmental influence on trip length. Transit use varies primarily with local densities and secondarily with the degree of land-use mixing. Some of the density effect is undoubtedly due to better walking conditions, shorter distances to transit service, and less free parking. Walking varies as much with the degree of land-use mixing as with local densities. The third D, design, has a more ambiguous relationship with travel behavior than do the first two. Any effect is likely to be a collective one involving multiple design features. It also may be an interactive effect with other D variables.

Table 3. The D variables

D variable	Measurement
Density	Density is always measured as the variable of interest per unit of area. The area can be gross or net, and the variable of interest can be population, dwelling units, freight facilities/generators, employment, or building floor area (e.g. square feet). Population and employment are sometimes summed to compute an overall activity density per areal unit.
Diversity	Diversity measures pertain to the number of different land-uses in a given area and the degree to which they are balanced in land area, floor area, specialized development, or employment. Entropy measures of diversity, wherein low values indicate single-use environments and higher values more varied land-uses, are widely used in travel studies. Jobs-to-housing or jobs-to-population ratios are less frequently used. From a freight perspective, freight village concepts in Europe seek to offer at least three modal options located at the intersection of long-haul and last-mile corridors.

D variable	Measurement
Design	Design measures include average block size, proportion of four-way intersections, and number of intersections per square mile. Design is also occasionally measured as sidewalk coverage (share of block faces with sidewalks); average building setbacks; average street widths; or numbers of pedestrian crossings, street trees, or other physical variables that differentiate pedestrian-oriented environments from car-oriented ones. For freight, design measures include pavement, bridge, and geometric design factors that can accommodate large trucks, and in some cases (depending on the regional economy) over-weight or over-dimension vehicles.
Destination accessibility	Destination accessibility measures ease of access to trip attractions. It may be regional or local. In some studies, regional accessibility is simply the distance to the central business district. In others, it is the number of jobs or other attractions reachable within a given travel time, which tends to be highest at central locations and lowest at peripheral ones. The gravity model of trip attraction measures destination accessibility. Local accessibility is a different animal, usually measured as distance to the nearest trip attraction of a given type. For freight destination accessibility is viewed from the end-to-end supply chain and the availability of freight services and modes to corridor shippers.
Distance to transit/alternatives	Distance to transit is usually measured as an average of the shortest street routes from the residences or workplaces to the nearest rail station or bus stop. Alternatively, it may be measured as transit route density, distance between transit stops, or the number of stations per unit area. In this literature, frequency and quality of transit service are overlooked. In a freight context distance to alternatives is measured by the shortest route to modal alternatives such as rail or barge.
Demand Management	Demand management measures the costs of driving and parking. As costs increase, travelers tend to shift to non-driving modes, and households tend to own fewer automobiles. Demand management is most often operationalized as parking supply or cost but may also include costs associated with congestion pricing, high-occupancy toll (HOT) lanes, or no-drive policies on roadways; incentives for carpooling or using transit; or fuel costs. Demand management for freight has typically focused on time of day strategies that are able to move demand to off-peak hours.
Demographics	Though not a characteristic of the built environment, traveler demographics such as income, age, household size, employment, and

D variable	Measurement
	other socioeconomic variables are important predictors of trip frequencies and VMT. Trip generation is a function of socioeconomic characteristics and the built environment. Therefore, demographic measures are typically used in travel studies to control for socioeconomic characteristics of human populations. Hours of service (HOS) and workplace environment have become driving factors in the trucking industry. Many trucking firms have adopted regional market strategies that enable truck drivers to complete their routes in a single day (per HOS regulations) and return home each night.

None of the published studies on corridor management use the 7-D framework explicitly; however, there are significant overlaps between the D variables and the variables of interest in corridor studies. A few examples follow:

Density: Several corridor management studies have developed models that examine the density of various land-uses along transportation corridors, including a GIS-based model assessing the sustainability of transit-oriented development (Chen, Huang, & Zhang, 2012) and another assessing how transportation infrastructure could influence redevelopment (Bardhan, 2013). Similarly, Zhu, Xiong, Chen, He & Zhang (2018) created an agent-based travel-behavior model to estimate transportation impacts from various development scenarios. Density is also a factor in defining "critical freight corridors" as directed in the Fixing America's Surface Transportation (FAST) Act (see 23 U.S.C. § 167).

Diversity: Studies focused on integrating land-use and transportation planning often examine the mix of land-uses. Litman (2019) examines how transportation decisions affect land-use patterns and the resulting economic, social, and environmental impacts. These include direct impacts on land-used for transportation facilities and indirect impacts caused by changes to land-use and development patterns. Rooney, Savage, Rue, Toth & Venner (2010) identify and explore successful innovations in integrating transportation and land-use planning for transportation corridors, with a focus on practices that could be transferred to other locations. Zhu, Xiong, Chen, He & Chang (2018) use dynamic-traffic assignment and agent-based models to estimate the transportation impact under cumulative land development.

In the freight context, the concept of freight villages originated in Europe seeks to develop logistics centers that co-locate clusters of transport and related support facilities (fuel stations, repair shops, postal services, etc.). Higgins and Ferguson (2011) examined how the freight village concept might complement the Ontario-Quebec Continental Gateway and Trade Corridor Initiative. The study found that there are a wide array of freight village developments (as well as many names for them), and as a first step in the research devised a hierarchy of the freight village concepts. The research found that central to the freight village concept is connections to major highway and multimodal corridors.

Design: There is overlap in the way the 7-Ds framework has been used to correlate travel behavior and the design of local streets and the way corridor studies look at highway facilities. Belisle, Torres, Volet, Hale & Avr (2019) evaluate ramp-metering algorithms and other methods to mitigate merge impacts at freeway bottlenecks. Yang, Cheng & Chang (2018) develop a control system that coordinates off-ramp queue estimation, arterial adaptive signal operations, and freeway priority control.

In a freight corridor context, design is often focused on pavement and bridge integrity or strength, as well as highway geometric designs to accommodate large and/or oversized or overweight transport and military vehicle.

Destination Accessibility: Previous studies have identified a host of new tools to quantify destination accessibility within transportation corridors. Shi & Zhu (2019) use mobile phone signaling data to quantify the trip volumes and spatial distribution of travel within a network after identifying residential and employment locations of travelers. Dzumbira, Geyer Jr. & Geyer (2017) observe travel between a transportation corridor and nearby nodes to determine the accessibility of the network.

Distance to Transit/Modal Alternatives: Aboelnaga, Toth & Neszmelyi (2019) found that the proximity to transit is a major factor in the success of mixed-use and transit-oriented developments in catalyzing urban redevelopment.

The distance to non-highway corridors such as rail and inland water corridors has been a frequent topic of research on the competitiveness of commodity movements, especially in the wake of major policy changes such as deregulation in the U.S. rail industry in the 1980s. In 2012, Canada transferred the responsibility of overseeing the marketing and transport of western wheat from the Canadian Wheat Board to the private sector. In the wake of this policy change, Gleim and Nolan (2014) used a GIS platform to simulate grain movements under several scenarios, including the so-called “pipeline” model where Class 1 railroads only move grain on their main corridors.

Demand Management: Corridor management studies examining strategies to reduce travel demand in transportation corridors focus more on shifting the timing of peak travel periods than on parking policies as in the 7-D framework, but both are concerned with optimizing the capacity of existing transportation infrastructure. Prodan & Teixeira (2018) evaluate the impacts of capacity allocation and infrastructure pricing policies by applying project evaluation guidelines normally used for new infrastructure projects. Liu, Zhang, Kwan, Wang & Kemper (2013) quantify the performance of integrated corridor management practices by observing the effect of traffic diversions to adjacent arterials during freeway incidents on network-wide operations. Hashemi & Abdelghany (2018) and Mahmassani & Jayakrishnan (1991) examine how providing drivers with information on traffic patterns can reduce vehicle congestion.

Demographics: Property values and demographic factors are key variables in a model Bardhan (2013) develops to predict how land-uses surrounding a new transit facility could change in the future.

1.6 Conclusions

A central challenge of a corridor management impact framework is balancing the need for efficient vehicle movement with local quality of life and economic development. Just as land-use planning seeks to arrange industrial, service, and residential activities to ensure the highest and best use of places, corridor planning seeks to utilize infrastructure in support of these highest and best uses. However, in many cases, the work of corridor management has fallen largely to state transportation agencies, which tend to be less focused on economic development and growth management. The purpose of this effort is to identify innovative corridor management practices that help agencies manage the two-way interactions between land-use decisions and economic development at the metropolitan scale while also improving travel times, delay, fuel consumption, and emissions, and the reliability and predictability of travel within corridors themselves.

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Appendix 2
State of the Practice Review

2.1 Introduction and Executive Summary

The objective of this report is to document the current state of corridor performance impact analysis and to discuss elements for enhanced planning and corridor management frameworks. In addition to a literature review, this report reflects a series of records profiling of over forty corridor studies, corridor management programs, and other current practices related to corridor planning and management.

While the report includes citations in addition to the previous literature review, its principal source of information is a series of unpublished "real world" corridor studies, policies, and other examples of practice compiled and shown in the Appendix 1 literature review, the Appendix 3 case research, and the database in Appendix 9. This scan of existing practice is housed in Appendix 9; Corridor Innovation Database. The records in the database represent (1) a diversity of corridor studies addressing passenger and freight corridors at different levels of scale and complexity, (2) intentional representation of intra-state and multistate examples as well as studies motivated by a wide range of policy contexts. Statements made in this report reflect observations of corridor impact measurement seen in the practice of corridor management efforts relative to the availability of sources, methods, and performance indicators cited in Appendixes, 1, 3, and 9. Where there is not a literature source cited for any given observation in this document, it is intended to be understood that the observation is rooted either in the prior literature review or (as in most cases) in the interpretation of the examples of practice in the corridor innovation database.

The review begins with an exploration of the evolution of corridor management and the role of quantitative impact measures, providing context for how and why the existing practice stands as it does. The findings include interpretations from a cursory review of corridor-related efforts throughout the United States in launching a corridor innovation database (Appendix 9). Observations are made about the ways that corridor management is in different contexts and how these contexts relate to impact measures. Special attention is given to the unique needs of suburban and urbanizing areas, and the relationship between growth management and corridor management. High-level frameworks and their use of performance measures are explored in-depth concluding with gaps in existing practice and opportunities for a new corridor impact measurement framework outlined in the Playbook.

2.2 Initial Observations from Practice

The review finds that despite a wide range of indicators and methods that have been applied in selected instances, the primary objectives of nearly all management efforts have been to improve speed and reliability, sometimes through actions meant to increase the safe design speed, but mainly through efforts to minimize delay caused by recurring congestion or by incidents. Beyond speed and delay objectives, other objectives that are significant in nearly all cases have been to achieve the best possible safety for the desired design speed and to be sensitive to environmental contexts. About 30% of records reviewed had significant exploration of investing in alternative modes of passenger transport, but that discussion is usually divorced from any discussion of how corridor design elements can encourage, or hinder land-uses that would be popular with alternative modes. About 20% included the term “Complete Street,” but usually in the context of providing better safety and mobility experiences for today’s existing and latent demand for alternative modes.

There was little recognition that a strong motivator behind the Complete Street movement is to address future demographics that are expected to see far more people unable to drive, or at least hoping to avoid driving as often as possible. Another under-recognized driver behind Complete Streets is to catalyze more sustainable development, for the sake of climate change, public health, reduced infrastructure burden, and revitalizing distressed Greyfield locations. The “7-Ds” are referred to several times in this document (can be sourced back to the original literature review in Appendix 1) and were first identified as pathways for creating successful activity centers that reduce Vehicle Miles Traveled. The D’s include 1) **Density** of land-use, 2) **Diversity** of land-uses, 3) **Design**: Complete Streets and connected networks, 4) **Destinations** of regional significance, 5) **Distance** from Transit, 6) appeal to **Demographics** who are interested in alternative modes, and 7) some level of **Demand Management.**

About 30% of the records reviewed had a significant focus on multimodal freight transport, mainly to improve economic vitality, and reduce the congestion and maintenance burden of trucks on highways. Just 10% appeared to involve any significant discussion of Travel Demand Management.

2.2.1 Corridor Management means different things to different people

There is a considerable body of knowledge regarding what is meant by “corridor management” relative to “corridor planning.” The earlier literature review for NCHRP 08-134 revealed that that corridor management means different things to different people. Here are some perspectives from different professionals:

- To DOT planners/project managers, corridor management has been largely synonymous with “Integrated Corridor Management (ICM),” Planning for ICM typically starts with bringing all parties with operational or oversight responsibilities in a corridor into the planning process, and then visioning corridor operations based on better use of technology and information.
- To an Intelligent Transportation System (ITS) manager it generally means the technology implementation and the use of “real-time” information to make corridor decisions. For example, using ramp metering, and providing traveler information to allow drivers to make decisions about alternate response and detect an incident quickly when it occurs.
- For freeway managers, it tends to mean interchange performance optimization, HOT lanes, ramp metering, creating or managing nearby freight rail or transit, and other strategies meant to reduce congestion and improve safety.

- For transit managers, corridor management is exclusively urban, and often means passenger amenities meant to attract commuters out of their cars, including fixed-guideway transit that can operate reliably when nothing else can.
- To freight planning managers, corridor management typically takes a trade or commerce focus to connect often distant markets. Freight metrics tend to focus on cost and reliability.
- To regional MPO planners, corridor management is increasingly connected to making linkages between transportation and land-use, to reduce VMT and increase the use of Alternative Modes.
- To a municipal engineer, corridor management often means consolidating driveways, installing raised medians, and optimizing both safety issues and delay caused by at-grade intersections.
- To communities, corridor management is increasingly synonymous with Complete Streets and traffic calming as a means of revitalizing Greyfield uses, addressing public health, and attracting people away from cars through safe and attractive alternative mobility options.

The various viewpoints about what corridor management means, suggest a simple but relevant framework for describing essential functions associated with owning and operating a transportation network, or in this case a transportation corridor: 1) Planning and Investment; 2) Design and Construction; 3) Maintenance and Operation, and 4) Regulation and Revenue Collection. This simple framework is shown in **Figure 1**. The diagram expresses the cycle of recurring activities, some of which happen only periodically like planning and investment, and others that happen nearly continuously such as maintenance or revenue collection. It also places often disconnected or obscure functions like safety or weight enforcement in the same environment as other corridor activities like planning and construction. Finally, the diagram suggests that corridor management is an activity that crosses not only institutional jurisdictions, but functional activities as well.

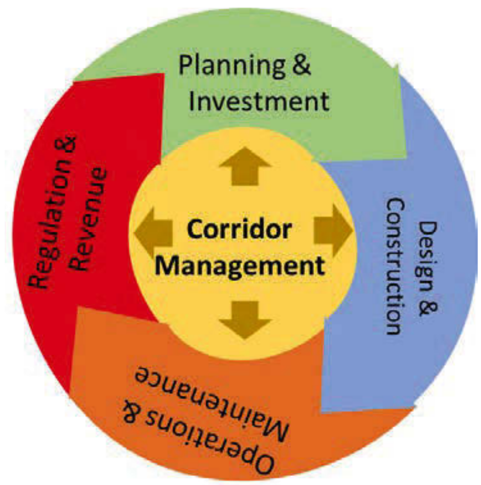

Figure 1 Functions of Owning/Operating a Transportation Corridor

From a review of corridor management practices, it seems apparent that the planning-level application of corridor management has focused strongly on maximizing modal efficiency for freight and on maximizing throughput and mobility for vehicles in general, with limited exploration of better integration with land-uses and the surrounding development process. Given the inter-dependency between corridor outcomes and the surrounding development process (and changes in corridor users) over time, the limited treatment of economic development in corridor management efforts has intuitively placed limitations on the effectiveness of corridor strategies. Articulating and developing a broader framework for addressing how to comprehensively measure and track all impacts, including land-use impacts of these often disparate corridor management activities, is the focus of this research.

2.2.2 Management is historically about speed, capacity, reliability, and safety

As indicated previously, it could almost be said that the term "corridor management" in practice has been nearly synonymous with strategies that help assure vehicles can travel reliably, with the least congestion possible, at an appropriate speed and a good safety record for the context of the corridor. Even studies that have considered funding, economic impact, livability, and other considerations have done so (and presented these issues) as tangential to speed and safety prerogatives. From a corridor planning perspective, corridor studies are not a new phenomenon. The literature review and corridor planning studies profiled for this effort, however, suggest there is no clear definition of what constitutes a corridor study, how one should be conducted, or even what should be assessed beyond well-accepted metrics associated with safety, access management, congestion, delay and, reliability. The default construction of corridor studies has fallen back on the most universally available and readily comprehensible performance framework, which are the AASHTO methods governing intersections and roadway segments, with other factors largely treated as add-ons or secondary factors.

Both the earlier literature review and the profiling of existing corridor studies yield relatively little corridor management emphasis on activities that happen under the Design and Construction function or the Regulation and Revenue function. Intuitively it is difficult for an agency to explore management strategies for those things over which an agency has little or no control, a likely reason there seems to be only minimal attention to land-use planning in the existing literature. Land-use is frequently a regulatory practice that happens at the local government level, city councils or county planning commissions set land-use ordinances usually to maximize tax receipts and create jobs. NCHRP Synthesis 332 offers institutional arrangements for shared authority, responsibility, and resources in corridor management, but based on a review of corridor management practices, coalitions entering into such joint arrangements are not the norm.[36] However, the vast majority of corridor studies and frameworks currently employed either (1) do not involve corridor coalitions or (2) involve coalitions largely as an advisory body for administering DOT-funded studies focusing on improving speed and safety with the support of local and private sector partners. The actual business or economic interests of such partners in the underlying economic potential of the corridor is either absent, or only tangentially addressed, and not measured in any consistent way. While some examples exist, there does not yet exist in practice, a class of corridor studies that make the business case for shared investment, shared risk, and shared opportunity through the process of corridor management. Given this finding, one opportunity for a more robust corridor impact framework may be to clearly demonstrate the incentives and payoffs that agencies (and private entities) at all levels may have for entering into and fully investing in such coalitions.

[36] Marc A. Butorac, Jerilyn C. Wen, and Kittelson & Associates, Inc., “NCHRP Synthesis 332 Access Management on Crossroads in the Vicinity of Interchanges A Synthesis of Highway Practice ,” 2004, https://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_syn_332.pdf.

2.3 Evolution of Corridor Management Paradigms

2.3.1 Contexts for Current Corridor Management Practice

While the above findings pertaining to the limitations in corridor management impact measurement are not surprising, it is notable that the current state of the practice does offer a foundation for a new and more comprehensive framework. The review of practice has included a number of existing planning frameworks and contexts that can be used to help establish a new, broadly based contextual planning and management paradigm. One such framework is the 7-D Framework, consisting of the 7-D elements enumerated in the introduction. The 7-D Framework is a method to help transportation agencies and stakeholders both measure and understand the interactions of transportation corridors with dependent land-uses. Traditionally, agencies focused on transportation metrics when assessing corridors and evaluating alternatives. The 7-D Framework allows for a broader quantifiable and contextual understanding of corridors and systems of corridors. Another related framework that helps practitioners broaden their view of a corridor is Complete Streets. Principles of optimization can also inform the structure of corridor studies, as increasingly data and techniques are available to create corridor designs and strategies based on performance specifications, as opposed to simply “testing” different possible strategies against established criteria through scenario planning.

2.3.2 Home Rule and Land-Use Planning Authority

Transportation professionals and planners in particular often view long-range planning as including the integration of community land-use plans with managing transportation corridors. However, most states have some form of “Home Rule” statute providing local governments with the authority to set land-use ordinances. Many of these home rule statutes were established in the late 1800s predating the planning and construction of many major corridors. The ability to change routine land-use practices will likely depend on the ability to educate locally elected officials (and the electorate) of the benefits of integrated land-use and transportation planning. This legal context shaping land-use and growth management authority in most settings makes the current state of the practice in addressing land-use for corridors by necessity a collaborative and inter-governmental process. The role of local planning and land-use authority will be further addressed both in this report and in subsequent case studies and frameworks.

2.3.3 Long-Range Planning

While project-based plans help states and regions understand the scope of transportation improvements needed to meet future travel demand and the projected financial resources required to meet that demand, the long-range planning requirements of transportation law for states and MPOs provide a systems perspective on both investment and performance. Federal requirements (and the body of research) on performance-based Metropolitan and Statewide planning requirements are understood as a starting place for understanding corridor impacts. However, it is further observed that in the state of the practice – corridor studies seek to bridge the gap between programmatic or system-level needs identified in the planning process and beneficial projects that can be readily delivered in a transportation program (STIP or TIP). From the available profiles, and the literature three areas are noted where an enhanced corridor impact framework can most readily improve the state of the practice: 1) Clearly defining the purpose of long-range plan projects; 2) Setting reasonable expectations, and 3) Partnering and collaboration, and planning in times of rapid and disruptive change.

Purpose of Long-Range Plan Projects: In the observed cases of corridor management efforts and impact measures, two sets of requirements are commonly reconciled. First, federal requirements for state and federal LTRPs couch investments in terms of overall system performance, making the purpose and need of investments seemingly intuitive (at least from the systems perspective), but often leaving open questions regarding whether any given project (or a specific build or modernization option for a particular project) is actually the best fit for an identified performance need. Second, federal environmental requirements (most notably NEPA) apply rigorous standards of purpose and need as well as alternatives analysis beyond what can be practically addressed for every need in an LRTP. In practice, corridor management is often used by agencies to bridge the gap between the systems perspective of the LRTP and the project perspective of NEPA.

The fact that this gap is recognized in the existing practice of corridor studies provides a starting point for a more robust understanding of corridor management impacts. The potential to interject other processes (such as the local comprehensive planning process, local economic development strategies, and other initiatives), with their associated data, analytics, and business intelligence is evident from many corridor studies. ***While many corridor studies profiled have considered a wider range for planning processes supportive of corridor management – there has not been a consistent framework for when and how to obtain and incorporate their findings and insights into a measurement paradigm. (For example, even widely available data such as assessor data of property value, trends in building permits, and public health statistics appear in very few corridor studies to date, yet these and other resources can clearly identify potential sources of management need and value in corridor management outcomes).***

Reconciling Expectations: A common feature of the current practice in evaluating corridor management impacts is the presence of local, regional, state, and federal partners as well as private entities. Because the partners have different governing structures and constituents and can have different missions, visions, goals, and objectives, corridor management provides both a need and an opportunity to utilize these different vantage points. The recently published *NCHRP 917: Right-Sizing Transportation Investments: A Guidebook for Planning and Programming* (2019) focuses explicitly on addressing the widely divergent perspectives on the efficient investment level and mix of performance outcomes that can or should be expected from a transportation system or sub-system. Some of the key findings of *NCHRP 917* relevant to a next-generation corridor impact framework include (1) the need to explicitly identify and quantify sources of value as realized by different corridor stakeholders, (2) identify the degree of risk and investment that partners in the corridor management process can reasonably be expected to incur to achieve these sources of value, and (3) establish some means of accountability in ongoing corridor partnerships.

Methodologies such as the Stratified ROI calculator recommended in *NCRHP 917* may serve as a starting place, which if joined with 7D variables and data from state, local, and private sources can provide the existing "state of the practice" building blocks for a new framework. ***It is found that existing practice often gets the right partners to the table, often with the right information and motivations, yet often without a way of using and bringing forward their perspectives yielding a clear understanding of intended payoffs and investments for each partner.***

Planning During Times of Rapid Change: Today's corridor studies similarly treat change and uncertainty to the paradigm of long-range plans. Effectively, much like long-range plans, today's corridor studies are based on knowledge of existing conditions in relation to some pre-formulated standard of performance and work through a series of alternatives or scenarios to explore how different investment or policy strategies may ensure ongoing or future achievement of these objectives for different costs. *Strategic Issues Facing Transportation, Volume 1: Scenario Planning for Freight Transportation Infrastructure Investment (2013)*, while oriented towards freight planning, provides a reasonable overview of how uncertainty is currently addressed through scenario planning and the use of impact metrics in the process.[37] Corridor studies today are found to favor the use of travel demand and micro-simulation models and in rare cases economic impact models (such as REMI and IMPLAN), and at times may use the air quality and noise models common to the NEPA Process when considering future scenarios. It is far less common that ex-post evaluation tools like PlanWorks and EconWorks, despite their presence online since completion of the Strategic Highway Research Program (SHRP) 2 initiatives – there is not a single documented corridor management study or framework utilizing these resources to address change or uncertainty in a scenario planning context.[38]

In almost all cases, existing corridor studies use scenario planning to test possible designs or policies in a future that is assumed to be fixed in all respects except for the policy-sensitive factors of the scenario. For example, every corridor study reviewed that considered futures always assumed that technology, economic growth, and underlying (background) traffic patterns were fixed and that only the scenario attributes would vary. This is intuitive and it allows forward-looking impact analysis to isolate which features can affect performance. However, the current practice fails to take into account the possibility that the benefits of a particular scenario may be predicated on implausible assumptions about economic growth or technology. In this case, a change in economic conditions, technology, or other factors may obviate both the needs and benefits (and undermine the intended performance impact) of the corridor management action. For example, a trade corridor study may find a preferred alternative of expansion, access, and safety improvements to emerge as a preferred alternative in 2019. Then in 2021 a trade agreement is re-negotiated, and two major industry sectors are automated, shifting demand patterns and by 2029 new vehicle technologies are deployed evaporating the crash trend on which the safety projects are predicated.

Not a single corridor study has been observed to test its findings for sensitivity to such potential change. Furthermore, all of the corridor studies and frameworks observed began with existing or projected deficiencies and tested scenarios. None began with projected needs/deficiencies to create a desired performance profile and worked backward to arrive at a scenario, despite a growing body of optimization literature suggesting that big-data and modeling capabilities make such processes possible. ***It is found that the future-testing scenario planning process engaged in the LRTP process and associated guidance literature comprises the current state of the practice for addressing future uncertainty in corridor performance. It is also found that there is significant room to more explicitly address the uncertainty of various types and to utilize optimization principles in the creation of future scenarios.***

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[37] Chris Caplice and Shardul Phadnis, "Strategic Issues Facing Transportation, Volume 1: Scenario Planning for Freight Transportation Infrastructure Investment," December 2013, https://doi.org/10.17226/22628.

[38] US Department of Transportation, "US Department of Transportation," Welcome - PlanWorks | Federal Highway Administration, accessed October 26, 2021, https://fhwaapps.fhwa.dot.gov/planworks/; "Welcome to EconWorks," EconWorks Improved Economic Insight, accessed October 26, 2021, https://planningtools.transportation.org/13/econworks.html.

2.3.4 Visioning

Many areas have used, and are using, "visioning" as means to foster dialogue and improve understanding of the interrelationships between transportation improvements, land-use changes, economic activity, jobs, housing, and quality of life. Such efforts are featured on FHWA's web page on linking transportation and land-use.[39] The Strategic Highway Research Program (SHRP 2) Report S2-C08-RR-1: Linking Community Visioning and Highway Capacity Planning provides a helpful overview of this process.[40] It is found that visioning plays a constructive role in establishing desired impacts in most corridor studies, raising significant public interest, and creating opportunities to address issues that may otherwise be missed. However, it is also found that corridor frameworks and studies based on comprehensive visioning often lack the institutional implementation and accountability provisions to enable consistent follow-through. ***There were very few efforts profiled that had administrative or legal provisions or agreements to explicitly establish accountability for drivers of corridor impact (such as land-use controls or private/local investment) that were beyond the control of the primary sponsoring agency.***

2.3.5 Corridor Planning

Transportation agencies have used federal requirements for long-range planning, NEPA, and project development activities to develop internal workflows aimed at ensuring compliance with those requirements. This has led to consistency in how these processes are completed, not only within transportation agencies but across agencies and states. However, since there is no federal requirement for corridor planning, transportation agencies have used corridor planning, and its many definitions, as situational remedies for specific issues.

Inconsistent Use of Corridor Planning Activities: Corridor studies are not a new phenomenon. DOT's, MPO's and local governments have long used corridor studies to assess corridor improvements. The literature review and corridor planning studies profiled for this effort, however, suggest there is no clear definition of what constitutes a corridor study, how one should be conducted, or even what should be assessed beyond traditional metrics like safety, access management, congestion, delay, and reliability.

Planning and Environmental Linkages (PEL): Planning and Environmental Linkages (PEL) could be an important element of improving the efficacy of planning. The widespread application of this tool has not happened, even for DOTs with full NEPA assignments. This means that much of the work completed in planning must be redone in NEPA. A reason for this is the inconsistent use of corridor planning and the lack of formal, contextually base corridor planning frameworks geared toward meeting federal PEL requirements.

In both of the corridor planning gaps listed above, a solution is the development of transportation agency contextually based corridor planning frameworks that fill the void between long-range planning processes and NEPA review processes.

Better Feedback Loops: The corridor function graphic in **Figure 1** is designed to suggest that the performance of one function's activities should inform the other functions. For example, operational

[39] Mike McKeever and Bruce Griesenbeck, "Linking Transportation and Land Use," FHWA, accessed October 26, 2021, https://www.fhwa.dot.gov/policy/otps/innovation/issue1/linking.cfm.

[40] Cambridge Systematics et al., "Linking Community Visioning and Highway Capacity Planning," 2012, https://doi.org/10.17226/14580.

activities like average speed or number of crashes are collected as performance information that is cycled back into the next planning activity to identify solutions that create the highest benefit to cost. With the review of corridor management research, the impact of other functional areas such as regulations (e.g. truck lane restrictions, designated truck routes) or pricing schemes (gas tax rates, variable toll lanes, ramp metering, etc.) lack the same type of performance measurement and lack any feedback loops. In other cases, activities related to functions like design and construction may be measured for one group of users, but not all. For example, Complete Streets often focus on pedestrian or bicycle users with no thought to freight haulers.

2.3.6 Planning is critical to project development

Despite having to work within the context of local land-use ordinances, long-range planning is typically the first step in project development. Before any potential solutions are seriously explored, a best-practice corridor planning effort brings together various stakeholders, gains consensus on the needs and opportunities that should be addressed. Long-range planning is about establishing a vision of what stakeholders hope to advance through actions that can be taken for the sake of the corridor and its dependent interests. Community-driven visions for transportation are increasingly moving beyond vehicular mobility and safety to include climate change, public health, economic vitality, land-use objectives, and enhancing the attractiveness of alternative modes.

Using the vision as a guidepost, goals and objectives are agreed upon, and potential solution sets are ranked by some objective criteria. To make decisions, stakeholders not only need performance metrics that are connected to their goals and objectives, but they also must prioritize how much they care about each objective relative to the others. Is safety more important than mobility? If so, lower-speed alternatives may be ranked higher.

2.4 What is Corridor Management? It Depends...

To date, most corridor management seems to have focused on major freeways, and corridor management has meant actions that improve the efficiency of traffic lanes or segregating the users of those lanes. On at-grade arterials, management has traditionally been driven by state DOTs reacting to land-uses that they believed were creating excessive side friction, safety hazards, or slow and congested conditions. The main goal has been to improve performance, which effectively has meant improving speed and capacity for vehicles and minimizing accidents between all modes, all with appropriate deference to cost, context, and environmental stewardship.

Going forward, both demographics and community needs are changing. Growing numbers from these interest groups are seeking to be heard. The state of the practice today is that corridor management means different things to different people, with diverging definitions emanating from various disciplines of the transportation profession. Based on the compilation of prior research and review of relevant corridor studies, several general conclusions will be presented here regarding the definition of corridor management historically and today.

2.4.1 Early Corridor Plans: Connecting Products to Markets

Some of the earliest defined corridor planning activities focused on opportunities to support or stimulate commerce and economic development. Before the designation of the national road and highway networks like the Interstate Highway System, National Highway System (NHS), or National Highway Freight Network (NHFN) many states defined important highways as key economic corridors, primarily in lesser developed rural areas. Farm-to-market route systems were designated in Texas, Iowa, and other agriculture states. Energy, mineral, and timber resources were important economic sectors in other states where improving access to markets resulted in special designations and focused investments in key corridors.

In 1991, the Intermodal Surface Transportation Efficiency Act (ISTEA) identified 21 highway corridors that were designated as *High Priority Corridors* (HPC), and to be included on the National Highway System (NHS). Congress reasoned that while the Interstate Highway System connected the most populous urban centers, some areas of the country remained inadequately served. The stated purpose of recognizing these HPS was: "*to prepare long-range plans and feasibility studies for these corridors; to allow the States to give priority to funding the construction of these corridors…"* (ISTEA Sec. 1105(b)).

In a short preamble to naming the first HPC designations, the bill notes: "the development of transportation corridors is the most efficient and effective way of integrating regions and improving efficiency and safety of commerce and travel and further promoting economic development. (ISTEA Sec. 1105(a)(3)).

Because the HPC program provided access to funding, by the end of 2005 the list of designated HPCs had grown to 80. Designated HPC corridors ranged from single highway facilities with a single state to multifacility, multijurisdictional and multinational corridors. ISTEA and the two subsequent reauthorizations included funds for both corridor improvements as well as planning. As a result of the HPC program, several prominent corridor coalitions were formed, such as the I-95 Corridor, Continental One Trade Corridor, North American Superhighway Coalition (NASCO), Ports-to-Plains Alliance, and CANAMEX Corridor among others. The initial planning studies associated with most HPCs were corridor-focused long-range plans that provided an inventory of corridor assets, identified corridor deficiencies, and included extensive stakeholder outreach. Most corridor plan recommendations included infrastructure replacement/upgrades and capacity expansion needs.

While the HPC jump-started corridor focused planning at the national level, there were also some notable corridor planning and management activities undertaken outside the HPC program:

- **Minnesota Interregional Corridors (IRC):** In 1999, Minnesota took a broad approach to defining key economic corridors at the state level, when it designated the IRC System. The IRC network focused on those highway corridors connecting "regional trade centers" (e.g. Rochester, Duluth) in Minnesota to the Minneapolis/St. Paul urban area. What makes the IRC effort in Minnesota notable was its early establishment of performance measures to track the ability of these priority corridors to provide timely and efficient transportation between trade centers.
- **National I-10 Freight Corridor Study:** This corridor effort between eight state departments of transportation (CA, AZ, NM, TX, LA, MS, AL, and FL) grew organically during discussions at several AASHTO meetings. While some segments of I-10 had been designated as HPC, the eight states formed a coalition and applied for a pooled fund study. The initial study evaluated seven scenarios to increase the long-term capacity of the corridor, using level-of-service (LOS) and speed as the primary evaluation metrics. Scenarios included adding lanes, modal diversion to rail and coastal

barge systems, ITS enhancements, more productive truck configurations, and truck platooning. A follow-on study focused on the ITS opportunities which resulted in an ITS corridor architecture. In 2007, the coalition successfully applied to a federal program entitled "Corridors of the Future." As one of just six interstate routes selected for the program, expectations were high, but when projects from only two of the ten states (AZ and LA) received project funding, the coalition dissolved. In recent years a new I-10 Corridor Coalition of CA, AZ, NM, and TX has reformed. The new coalition is less freight-centric and more technology-focused.

- **Freight Fluidity:** Beginning with an effort developed by Transport Canada to understand the performance of trips that goods make from a multimodal perspective, the concept of freight fluidity along key supply chain corridors has developed in the U.S. [41] The Federal Highway Administration (FHWA), and States such as Texas, Maryland, and Colorado have embarked on understanding freight fluidity in different ways exploring key origins and destinations, the trading partners and the critical corridors necessary to support freight flow through its entire trip. The use of industry-proven performance measures helps identify the bottlenecks and impacts on the transportation network. This information gives decision-makers direct information on opportunities to prioritize to support economic development and growth.[42]

2.4.2 ITS & IVHS: Corridor Planning Migrates to a Technology/Operations Focus

It's difficult to determine exactly when Intelligent Transportation Systems, or ITS, entered the lexicon of American transportation, but not only did ISTEA establish the HPC Program, it also established the Intelligent Vehicle Highway Systems (IVHS) Program. ISTEA also explicitly links corridor planning and ITS: "IVHS CORRIDORS PROGRAM- The Secretary shall designate transportation corridors in which application of intelligent vehicle-highway systems will have particular benefit and, through financial and technical assistance under this part, shall assist in the development and implementation of such systems."[43]

The IVHS section of ISTEA lays out eight goals for the program, with most seeking improvements to safety, air quality, and mobility using technology to improve congestion through more efficient operations. Just one goal broadly identifies opportunities to improve economic competitiveness through technology: "the enhancement of United States industrial and economic competitiveness and productivity by improving the free flow of people and commerce and by establishing a significant United States presence in an emerging field of technology."[44]

Many of the early IVHS corridor planning efforts were encapsulated as "Concepts of Operations" (ConOps). For example, following the Phase 1 scenario planning exercise, the National I-10 Freight Corridor developed a ConOps based on the adoption of advanced technologies and a corridor-wide ITS architecture in 2004/2005.

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[41] William L. Eisele, Louis-Paul Tardif, Juan Carlos Villa, David Lynn Schrank, and Timothy J. Lomax, *Developing and applying fluidity performance indicators in Canada to evaluate international and multimodal freight system efficiency* No. 11-0582 (2011); Transportation Research Board, "Advancing Freight Fluidity Performance Measures Summary of a Workshop," December 2015, https://onlinepubs.trb.org/onlinepubs/circulars/ec207.pdf.
[42] Bill Eisele, "Implementing Freight Fluidity in Texas," March 2019, https://onlinepubs.trb.org/onlinepubs/Conferences/2019/FreightData/FreightFluidityInteractiveEisele.pdf .
[43] Intermodal Surface Transportation Efficiency Act of 1991, Pub. L. 102-240, 105 STAT. 2193.
[44] Intermodal Surface Transportation Efficiency Act of 1991, Pub. L. 102-240, 105 STAT. 2189.

In 2006, USDOT launched the Integrated Corridor Management (ICM) initiative. In the same year, the agency published a high-level ConOps document for a generic 15 mile-corridor as part of the foundational research for ICM implementation. Early research focused on eight pioneer sites for ConOps development. Ultimately, two of these corridors, the US-75 Corridor in Dallas and the I-15 corridor in San Diego, were selected as pilot projects to demonstrate their ICM implementation. The ICM implementation in the I-15 corridor focused on managing traffic flows through dynamic ramp metering, changeable message signs, and dynamic variable prices on 21 miles of tolled lanes. The Dallas US-75 demonstration took a somewhat more multimodal approach that sought to use cameras and other incident detection technologies along with traveler information systems to push travelers to rail transit when incidents occurred.

ICM Pilot Performance Measures

Dallas – US-75 Measures

- Travel Time Reliability
- Increase Corridor Throughput
- Improve Incident Management
- Enable Intermodal Travel Decisions

San Diego – I-15 Performance Measures

- Travel Time
- Delay
- Throughput
- Reliability and Variance of Travel Time
- Safety
- Emissions and Fuel Consumption

Since these initial pilots, dozens of agencies around the U.S. have implemented ICM programs on major corridors. Nearly all these ICM projects have focused on three key opportunities: Institutional Collaboration, Intermodal/Operational Integration, and Technical Integration.

Institutional Collaboration: Most corridors whether focused on urban highway traffic or long-distance multimodal connections between economic centers involve multiple parties (public and private) who either own, operate, or simply host part of the corridor. Each of these parties influences corridor operations. Often corridor management strategies focus on facilitating communications and data sharing between corridor entities.

Intermodal/Operational Integration: Funding for the HPC program created by ISTEA was extended in the next two reauthorizations (TEA-21 and SAFETEA-LU). However, MAP-21 passed in 2012 did not appropriate funds to the HPC program. MAP-21 did extend funding to a program created in SAFETEA-LU; the Multistate Corridor Operations and Management Program. In 2012/2013 FHWA provided grants to seven multistate corridors. Most of these grants were used to further Integrated Corridor Management (ICM) projects across multiple states. The Great Northern Corridor study involving seven states examined a major Class 1 rail corridor and its connections to the multistate highway system.

In 2016, the findings from an AASHTO scanning tour were published as *NCHRP Project 20-68A, Scan 14-02: Successful Intermodal Corridor Management Practices for Sustainable System Performance.* The report highlights the different paths that corridor management has taken: "Intermodal corridor management builds on the principles of multimodal corridor planning, Integrated Corridor Management (ICM), and active traffic management. ICM recognizes that multiple modes can satisfy a variety of travel demands within a corridor and that most movement of people, goods, information, and services in a corridor involves movement between modes; it refers to a more tactical approach to operating primarily highways and streets for optimal results."

Technology Integration: Based on the review of the practice, many elements of modern corridor management were developed from early research into the possibilities of advancing ITS. Beginning in 2006, FHWA published a number of operational concepts examining the possibilities for using technology to improve corridor operations. "The basic premise behind the Integrated Corridor Management (ICM) initiative is that independent, individual network-based transportation management systems, and their cross-network linkages, can be operated in a more coordinated and integrated manner, thereby increasing overall corridor throughput and enhancing the mobility of corridor users."[45] The Effects of Speed-Focused Goals on Urban Land-use Patterns

2.4.3 Transportation Systems Management and Operations (TSMO) or ICM 2.0

In Moving Ahead for Progress in the 21st Century (MAP-21) the reauthorization bill passed in 2012 legislatively defined transportation systems management and operations (TSMO) as:

> "integrated strategies to optimize the performance of existing infrastructure through the implementation of multimodal and intermodal, cross-jurisdictional systems, services, and projects designed to preserve capacity and improve security, safety, and reliability of the transportation system." (MAP-21, Sec. 1103(a)(30)(A)).

The congressional definition of TSMO seems to emulate earlier descriptions of ICM. A couple of differences can be noted from reviewing literature and resources about TSMO. 1) Discussion of TSMO implementation efforts are not restricted to corridors, as is presumed in ICM strategies. 2) TSMO appears to more openly welcome multimodal and intermodal strategies as part of the toolbox.

On a resource page dedicated to TSMO, FHWA explains that TSMO should not be limited to deploying single or stand-alone solutions, stating that "TSMO ultimately involves a mindset to determine the best way to optimize the mobility and reliability of the existing system with limited resources." (FHWA website: Organizing and Planning for Operations[46]).

2.5 Corridor Management on Suburban Arterials

Because of their unique land-use patterns, suburban arterial corridors (or suburban arterial sections of corridors) are both instructive and important for both understanding and measuring the impacts of corridor management. An exploration of current suburban corridor characteristics, management strategies, and impact measures offers supports a current understanding of how land-use, transportation, and economic relationships combine to create corridor performance outcomes and suggests some specific ways that a more robust framework for understanding corridor impact can yield improved decisions.

[45] L. Neudorff, J. Harding, and L. Englisher, "Integrated Corridor Management, Concept Development and Foundational Research, Technical Memorandum," Integrated Corridor Management Concept Development and Foundational Research Technical Memorandum Task 2.3 — ICMS Concept of Operations for a Generic Corridor, April 18, 2006.
[46] https://ops.fhwa.dot.gov/tsmo/index.htm#q9

As indicated in the previous sections, freeways were the early focus of ICM, but more recent efforts are expanding ICM to corridors with many non-freeway segments. Maryland DOT has divided the state into over 20 ICM corridors, which includes many at-grade segments. But even as states expand their focus to at-grade corridors, state DOTs still tend to view corridors from a statewide perspective. At that scale, it is hard to value or even notice any negative impacts to localized land-uses from corridor management efforts, or to see opportunities to positively influence land-uses or other non-mobility objectives.

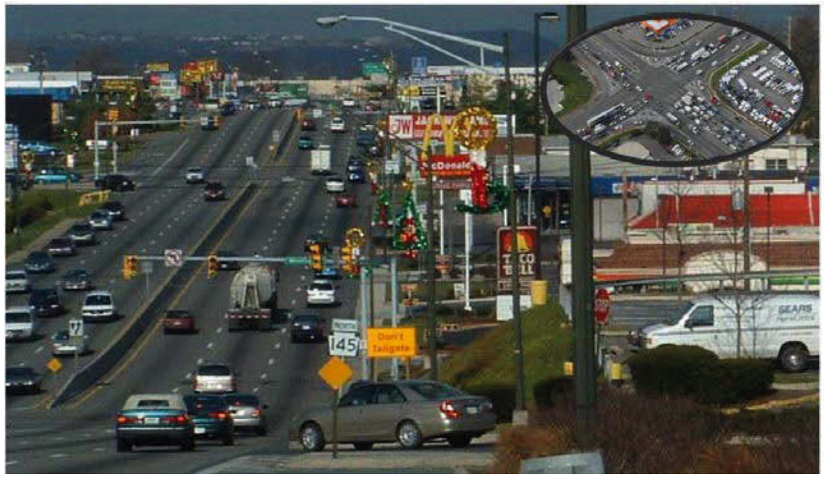

Figure 2 Typical Land-Use / Transportation Interaction on Suburban At-Grade Arterials

Prevailing definitions of "corridors" outside of state DOTs, (prevalent among the general public and many policy makers) understand a corridor not as something of national or statewide significance, but instead as "regionally significant," or even just locally significant. These corridors are usually at-grade, and around 3 to 10 miles in length. suburban America has a huge number of these at-grade arterials with 4, 5, 7, and even 9-lane cross-sections. While not of national significance, these at-grade suburban arterials are quite often the "first mile or last mile" of long multistate trips.

> Cor´ri`dor
>
> **n.**
>
> **1.** *(Arch.)* A gallery or passageway leading to several apartments of a house.
>
> **2.** *(Fort.)* The covered way lying round the whole compass of the fortifications of a place.
>
> **3.** any relatively narrow passageway or route, such as a strip of land through a foreign territory.
>
> **4.** a densely populated stretch of land; as, the Northeast corridor, extending from Richmond, Virginia into Maine
>
> *Source: Websters' Dictionary*

There is a growing interest in "Complete Street" changes on this type of corridor, and a significant desire to see these arterials better integrated with changing land-use needs. Thus, there is a need for understanding the impacts of traditional corridor management and associated land-uses on suburban corridors. According to the 2017 American Housing Survey, 52% of Americans describe their neighborhood as suburban.[47] Arterials serving suburban areas are easily observed to be large and are quite often the dominant feature in much of that space. The term "place-making" has resonated with suburban communities because they sense that land-uses along these arterials are so heavily auto-oriented that there are too few historic Main Street-style places for their

[47] "American Housing Survey (AHS)," American Housing Survey (AHS) - CKAN (Publisher US Department of Housing and Urban Development, November 12, 2020), https://catalog.data.gov/dataset/american-housing-survey-ahs.

citizens to go to, walk around, and enjoy.[48] This section describes the state of management practices for at-grade urban arterials and the effects of those practices on land-uses.

2.5.1 State of the Practice vs Best Practice in Corridor Network Design

Urban arterial corridors often face a need for aggressive management due to overwhelming demand that would leave them excessively congested and unsafe otherwise.[49] The deficiencies of urban roadway networks are due in large part to the state of the practice in network design (or lack of network design).

America has a 60-year tradition of 20-year plans, and that is a huge part of the reason that corridors today face overwhelming demand. Planning horizons are appropriate for fiscal need projections, but too short for build-out multimodal corridor needs estimation. When planners in 1960 looked at 1980, they did not clearly see the corridor needs that 1980 would bring, so from 1960 to 1980, haphazard development started to cut off prime locations for new corridor alignments of all scales: expressways, arterials, and even collector streets. A simple review of the US Census reveals that in most regions, population has usually kept growing beyond the horizon year.[50] That growth then overwhelms existing corridors, but it is too hard at that point to create new relief-valve corridors.

If one could go back in time 50-years or so, it is relatively easy with hindsight to see how much growth occurred between then and now, and one could from that reasonably predict how much more growth might happen on the fringes from now to some point well beyond the current planning horizon year. Unfortunately, America is still stuck in the rut of under-estimating post-horizon year needs, and thereby failing to recognize just how many corridors, including bicycle and transit corridors, will ultimately be needed. The recently complete *NCHRP 917: Right-Sizing Transportation Investments Methods for Planning and Programming Implementation Guidebook* highlighted an obscure recommendation from ITE's 1992 *Transportation Planning Handbook*, which recommended that greenfield areas that were likely to eventually urbanize, would be wise to preserve space for a freeway or expressway corridor every 5-miles, arterials every 1-mile, and collectors at least every half-mile.[51] Massive swaths of America's suburban landscape have far less than this.

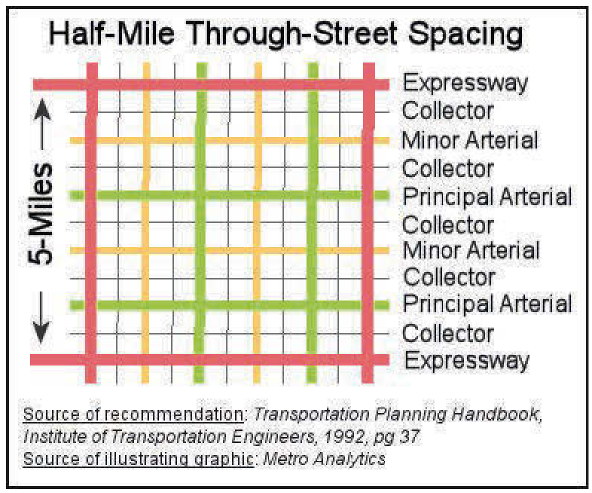

Figure 3 ITE Best Practice corridor spacing guidance, referenced in NCHRP 19-14 Right-Sizing guidebook

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48 "What Is Placemaking?," Project for Public Spaces, accessed October 26, 2021, https://www.pps.org/article/what-is-placemaking.

49 David Schrank et al., "2021 Urban Mobility Report," Mobility Division, June 2021, https://mobility.tamu.edu/umr/.

50 US Census Bureau, "Population Change for Metropolitan and Micropolitan Statistical Areas in the United States and Puerto Rico: 2000 to 2010 (CPH-T-2)," Census.gov, September 2011, https://www.census.gov/data/tables/time-series/dec/cph-series/cph-t/cph-t-2.html.

51 National Academies of Sciences, Engineering, and Medicine, NCHRP-917: Right-Sizing Transportation Investments: A Guidebook for Planning and Programming (Washington, DC, 2019), https://doi.org/10.17226/25680; "Transportation Planning," Institute of Transportation Engineers, accessed October 26, 2021, https://www.ite.org/technical-resources/topics/transportation-planning/.

This observation reveals the well-established principle that corridor performance must be understood within the context of the adequacy of the wider networks in which corridors operate. In **Figure 3,** the failure of any given roadway can readily be understood in terms of inadequate supporting and ancillary connections feeding and distributing demand within the larger system. In effect, the realistic impact objectives of managing any one of the facilities in Figure 3 can largely be assessed by understanding the adequacy of the surrounding network. Historic corridor management frameworks (even in fast-growing areas) have not been found to typically consider the impacts of multimodal network design as a corridor management scenario feature. While some have considered ancillary facilities as scenario attributes, there have not typically been impact measures applied to assess how the corridor management process contributes to the protection and preservation of new alignments or assets that support multimodal network resilience in the long term. In areas that are effectively built out when corridor management begins, discovering opportunities for efficient network spacing is far less than ideal, and the impacts of corridor management may be more limited, but also highly dependent on high-value opportunities to arrive at an improved network connectivity profile.

2.5.2 The Distressed Status of Land-Uses along Many Suburban Arterials

A review of existing corridor management efforts shows a consistent pattern regarding how congested suburban areas have come to have fewer through streets than would be ideal, and how two-lane highways have often become congested multilane highways with numerous safety conflicts. It is important to understand this trajectory and its relationship to both land-use development and efficiency when considering corridor impact measures. In the 20th century, it is reasonable to assume that when arterials have been first built at the fringe of urban development, new commercial development has most likely been auto-oriented. The newness and distance to other locations would make such auto-centric places vibrant and attractive. Thus, in the beginning, auto-oriented development was not a problem at the outset for 20th-century developments which, in the near term, were able to thrive on new businesses and the tax revenues from those businesses. As traffic volumes increased, both formal and informal corridor management efforts posed opportunities to retrofit such corridors in response to attendant congestion and safety issues. First, they may have been widened and multiphase signals are installed. Later, driveway consolidation, raised medians, and intersection expansions will be constructed.

2.5.3 Corridor Impacts in the Development Lifecycle

Very few existing corridor studies consider the relationship between a corridor management strategy and the real-estate turnover dynamics interacting with corridor performance. Considerations of the cyclical nature of land-use change and property as a function of roadway accessibility are almost fully absent from observed corridor studies in practice, either in their impact metrics, strategies, or evaluation criteria. **Figure 4** demonstrates a reasonably well-documented depiction of the cycle by which new infrastructure draws new high-value development, but the value of that development can become hostage to the access of increasingly deficient infrastructure which then warrants further investment in an attempt to sustain the initial development in an ongoing cycle. However, if the "Arterial Improvements" shown in the figure are limited to capacity and speed improvements addressing the obvious deficiencies, it leaves the unanswered question regarding the area's overall competitiveness,

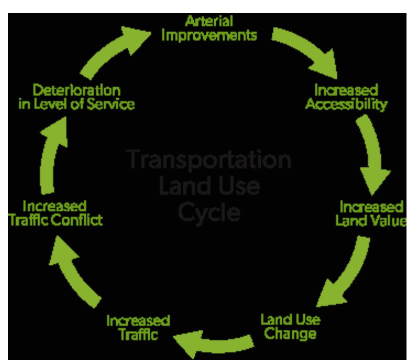

Figure 4 Capacity & Development Life Cycle Source: CMAP

and whether speed and capacity are even the performance areas that will determine such sustainability in the next round of the cycle.

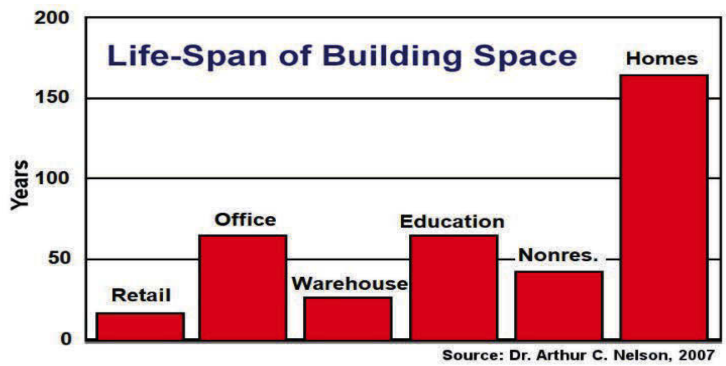

Figure 5 Typical life span of building types.

New research calls into question the observed practice of managing corridors primarily for safety and speed, on the assumption that the surrounding population-serving retail development will simply be sustained as well. In **Figure 5**, a 2007 study finds that the retail development that is built in a new area, on average lasts only 20 to 25 years before market pressure requires a significant face lift of the entire area, if not a complete reinvention, with higher densities and more diverse uses to remain attractive.[52] The research effectively finds that the retail businesses (which also include population-serving service establishments) that use the infrastructure will tend to re-assess their location against a full range of factors on approximately a 20-25-year basis. Other business locations, such as warehouses, also have shorter durations than some longer-term uses, such as offices, educational establishments, or homes. Hence corridor management becomes one of many factors contributing to a corridor's ability to sustain its business environment in this changing context, whereby simply sustained safety and mobility performance is not only an unremarkable impact, it may well be taken as a default assumption depending on the type of business mix the corridor seeks to sustain. In contrast to retail and warehouse locations, other non-residential uses tend to last 30-70 years, and residential uses so-far average 170 years. Much of the reason for the fast turnaround in retail locations has been its tendency to construct low-cost "throw-away" buildings scattered haphazardly amidst large surface parking lots reliant on direct corridor access. Another factor has been the arterials on which such areas rely for access eventually have both congestion and access control measures that make auto access more difficult. And because the environment is hostile to alternative modes, it is difficult to convert the properties to the alternative uses that are encouraged by alternative modes.

As the new luster wears off areas dominated by auto-oriented retail, many businesses either close or relocate to the next new greenfield development further on the fringe. At the older location, blight and under-utilized commercial space quickly ensue, as remaining businesses struggle for revenue to keep their properties attractive. This is the very definition of "Greyfield land," which has been defined as "economically obsolescent, outdated, failing, moribund or underused real estate assets or land," which does not have any environmental remediation required prior to redevelopment, but nonetheless does not redevelop due to numerous obstacles.[53]

If impact measures do not seek to gauge the match between the nature of the corridor improvement, or existing corridor characteristics, and where the corridor area stands in its development cycle. Corridor management practices meant to keep things moving for the sake of economic vitality may inadvertently contribute to the degradation of economic vitality. In many cases, land may languish indefinitely until the

[52] Arthur C. Nelson, "Arthur C Nelson Salt Lake Realtors 1 11 10 1[1]," SlideShare, January 15, 2010, https://www.slideshare.net/aubrob/arthur-c-nelson-salt-lake-realtors-1-11-10-11, Slide 16.

[53] "Greyfield Land," Wikipedia (Wikimedia Foundation, August 16, 2021), https://en.wikipedia.org/wiki/Greyfield_land.

corridor cross-section and management strategy changes in a way that allows the market to overcome additional obstacles to revitalization.

Addressing the development life cycle regarding corridor conditions is also important for reasons that are closer to state DOT missions, such as a common policy to preserve existing infrastructure before adding new infrastructure. When corridor cross-sections lack investments that support long-term land value stability, and land-uses along arterials subsequently degrade, it contributes to a “flight for the fringe” by both businesses and residents that can afford to leave. The result is fiscally unsustainable, duplicative infrastructure, much of which is under-utilized just as the land adjacent to it is under-utilized. The strong trend toward online retailing and home offices is also accelerating the Greyfield effect, leaving even more properties from yester-year’s popular locations severely underutilized. Corridor impact measures that take into account how corridor access, design, aesthetics, and other characteristics contribute to the long-term retention of the corridor business environment are likely to capture the potential value of corridor strategies more effectively than those that may focus on speed and safety performance alone.

2.5.4 State of the Practice in Successful Land-Use and Transportation Integration

Just as overlooking measures related to the development life cycle are observed as a common pitfall in today’s practice there are also examples of opportunities that can arise when such indicators are checked and integrated into corridor management. When land-uses along large urban arterials get stuck in a Greyfield situation, the formula for recovery can require higher densities, in part so that developers can recover through volume what is lost in initial land acquisition and in dealing with other retrofit-related obstacles that Greenfields do not have. Such revitalization also requires a scale of momentum, as small lot developers risk spending more on their properties than they can recover in leases because the best properties in an economically challenged neighborhood end up overwhelmed by the neighborhood.

Figure 6 Lancaster CA

This is much of the reason for increasing interest in Complete Streets and Form Based Codes, which often are developed together. In 2012, the National Complete Streets Coalition explored the before and after effects of several Complete Street investments in California.[54] An intriguing example is Lancaster Blvd in Lancaster, CA. Previously it had a 5-lane cross-section, and measured speeds were often 40-50 mph. Over the years, traffic volumes dropped due to failing businesses.

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[54] Smart Growth America, “The Best Complete Streets Policies of 2012,” Smart Growth America, April 2013, https://smartgrowthamerica.org/resources/the-best-complete-streets-policies-of-2012/.

In 2006, the city began planning for a Complete Street overhaul, and the core parameters of the new design were adopted in 2008. The corridor's performance and needs were understood in terms of emerging market trends, changing users, and dynamic land-uses. The primary objectives entailed a reduction of through lanes from four to two, and the introduction of angled parking, and a significant investment in street trees and pedestrian-oriented features. By 2010 it was open. The report notes that while the project cost was $10.4 million, private investment began as soon as 2006 in anticipation of the changes, and from 2006

Figure 7: City of Lancaster, CA Before and After

to 2012 reached $125 million. In just two years after opening, sales taxes in downtown were up 26%, forty new businesses had opened, 800 new jobs had come, and a hundred new housing units had been opened within one block of the boulevard.[55]

2.5.5 Status of Demographic Inequities along Suburban Arterials

Not so long ago, the number of Americans living in suburbs who didn't want to or couldn't drive seemed to be a relatively minor segment of the population. Nearly all teenagers, upon reaching age 16, would obtain a driver's license. Those living below the poverty line who couldn't afford to drive tended to live in or near CBD areas. In part due to shorter lifespans, the number of elderly citizens who couldn't drive was also comparatively low. The apparent lack of need for alternative modes led both communities and DOTs to merely accommodate these small groups as an afterthought rather than actively designing for them with the intent of increasing the scale of alternative mode use. More recently, all of these groups have been growing. For various reasons, including an increased desire to be environmentally responsible, young adults often do not want driver's licenses and instead are seeking active modes and transit as often as possible, supplementing with ridesharing and Mobility as a Service when necessary.

Longer life spans, retiring Baby Boomers, and a desire of many to "age in place," means the ranks of the elderly who can't (or shouldn't) drive are swelling quickly. And as for the economically challenged, the location of their mobility need is also changing quickly. Many central cities are rebounding economically, and thus the location of poverty is moving to the suburbs. On top of it all is an increasing desire among the middle-aged who can drive but want to fill more of their daily trips by active modes, primarily for health maintenance.

Since the number of people who would use alternative modes, if deemed safe, attractive, and practical for getting around, is increasing, the state of the practice in corridor management is also increasingly cognizant

55 "It's a safe decision: Complete streets in California," National Complete Streets Coalition, February 22, 2012, retrieved August 8, 2012 from http://www.completestreets.org/webdocs/resources/cs-in-california.pdf.

of this growing need. As of 2018, there were reportedly more than 1500 formal Complete Streets in effect, including 33 adopted by state governments.[56] But there are relatively few formal processes for considering how many of today's corridor management practices may be inadvertently contributing to excessive auto dependency. There is also room to explore more strategies for advancing Complete Streets while also maintaining good vehicular performance. There is significant potential to achieve both Complete Streets and better vehicle performance through Alternative Intersection design and other design strategies.[57]

2.6 Existing Frameworks for Monitoring Performance

In 2012 Moving Ahead for Progress in the 21st Century (MAP-21) was seen by many as a watershed moment for transportation policy, as the bill directed transportation agencies to establish performance and outcome-based investment programs. More specifically the legislation directed the USDOT Secretary to "establish and implement a national highway performance program" in seven areas:

- **Safety**
- **Infrastructure Condition**
- **Congestion Reduction**
- **System Reliability**
- **Freight Movement and Economic Vitality**
- **Environmental Sustainability**
- **Reduced Project Delivery Delays**

The resulting rules by USDOT require state departments of transportation and metropolitan planning organizations "to establish targets related to safety, bridge and pavement condition, air quality, freight movement, and performance of the National Highway System, and to use performance measures to track their progress toward meeting those targets."[58]

MAP-21 also noted that corridor management is one form of transportation systems management and operations (TSMO). MAP-21 defines TSMO as: "Integrated strategies to optimize the performance of existing infrastructure through the implementation of multimodal and intermodal, cross-jurisdictional systems, services, and projects designed to preserve capacity and improve security, safety, and reliability of the transportation system."

Multimodal corridors also fit the traditional concepts of ICM framework developed by the U.S. Department of Transportation. ICM refers to coordination among adjacent transportation facilities on operations and infrastructure investments to create an interconnected system capable of cross-network travel. Zhou, Mahmassani & Zhang (2008) note that, by taking advantage of advanced transportation analysis tools to estimate and predict network conditions and to analyze network performance, as well as communication and sensing technologies that provide an integrated, system-level perspective, ICM can improve travel times, delays, fuel consumption and emissions, and the reliability and predictability of travel within corridors.

[56] "Complete Streets Policies Nationwide," Smart Growth America, September 14, 2021, https://smartgrowthamerica.org/program/national-complete-streets-coalition/publications/policy-development/policy-atlas/.

[57] "New Ways to Manage Traffic and Create Great, Mixed-Use 'Places,'" Place Making Alternative Intersections, accessed October 26, 2021, https://innovativeintersections.org/.

[58] "Planning and Performance," U.S. Department of Transportation, accessed October 26, 2021, https://www.transportation.gov/office-policy/transportation-policy/planning.

This document opened with the suggested key functions for owning and operating a transportation system or corridor. Most notable is that the framework explicitly expands the functions and activities of corridor management beyond planning, construction, and operations. Regulation and revenue collection activities often fall outside DOT or MPO jurisdictions, but likely have a significant impact on corridor development. For instance, in the assessment of the state of the practice, it is noted that land-use is rarely a consideration in corridor management strategies. And land-use regulation is most frequently set by local ordinances as all, but a handful of states have enacted “Home Rule” laws bestowing land-use authority to local governments.

The assessment addresses the 7-Ds variables. These variables seek to reduce vehicle miles of auto travel through smart land-use and economic development policies, good infrastructure investments, and market-based pricing. Below is an expansion of the 7-Ds in relation to how they influence both passenger and commercial operations in a corridor:

Table 1: D Variables

D variable	Commuter Meaning/Metrics	Freight Meaning/Metrics
Density	Density is measured as the variable of interest per unit. Population and employment are sometimes combined for an overall activity density per area unit. Research suggests that as population density increases, VMT per capita decreases. Shorter trips are more likely to use alternative modes.	Industry clusters and the synergies around supply chain clusters is an emerging field of study. The interplay between population density and e-commerce/home deliveries is an area that could be explored in a corridor context.
Diversity	Diversity measures pertain to the number of different land-uses in a given area and the degree to which they are balanced. Entropy measures of diversity, wherein low values indicate single-use environments and higher values more varied land-uses, are widely used in travel studies. Jobs-to-housing or -to-population ratios are less frequently used.	Freight village concepts in Europe have sought to offer modal options and a variety of freight support services at the intersection of long-haul and last-mile corridors. Many European freight villages required subsidies to drive these developments. In the U.S. multimodal logistics centers are a close cousin.
Design	Design measures include average block size, proportion of four-way intersections, and number of intersections per square mile. Design is also occasionally measured as sidewalk coverage (share of block faces with sidewalks); average building setbacks; average street widths; or numbers of pedestrian	Freight design measures consider pavement, bridge, and geometric factors for accommodating large trucks and depending on the local economy, over-weight or over-size vehicles. In urban areas truck routes have historically sought to keep large trucks out of neighborhoods, vs. designating and

D variable	Commuter Meaning/Metrics	Freight Meaning/Metrics
	crossings, street trees or other physical variables that differentiate pedestrian-oriented environments from car-oriented ones.	designing routes that will attract trucks.
Destination accessibility	Destination accessibility measures ease of access to trip attractions. It may be regional or local. In some studies, regional accessibility is simply distance to the central business district. In others, it is the number of jobs or other attractions reachable within a given travel time, which tends to be highest at central locations and lowest at peripheral ones. The gravity model of trip attraction measures destination accessibility. Local accessibility is a different animal, usually measured as distance to the nearest trip attraction of a given type.	For freight destination accessibility is viewed from a supply chain perspective and the availability to reach important domestic and foreign trade markets through competitive alternatives. Captive shippers pay higher rates. Access to equipment can also impact accessibility. For example, specialty grain shippers in the Midwest often have difficulty accessing 20-foot intermodal containers required for moving grain on truck, rail, and ship to access export markets.
Distance to transit/alternatives	Distance to transit is usually measured as an average of the shortest street routes from the residences or workplaces to the nearest rail station or bus stop. Alternatively, it may be measured as transit route density, distance between transit stops, or the number of stations per unit area. In this literature frequency and quality of transit service are overlooked.	The private sector view of this metric might be better stated as time or cost to alternatives. Examples abound of "build it and they will come" projects seeking to use freight alternatives to foster economic development. Many of these projects fail or fall short of expectations because key industry supply chains are not well understood. Freight fluidity is a growing area of performance measurement on this topic.
Demand Management	Demand management measures the costs of driving and parking. As costs increase, travelers tend to shift to non-driving modes, and households tend to own fewer automobiles. Demand management is most often operationalized as parking supply or cost but may also include costs	Demand management for freight also focuses on costs, primarily for labor and fuel. Moving deliveries to non-peak hours in urban areas allows a driver more deliveries in the same amount of time, using less fuel. To be effective on a broad scale requires shippers and

D variable	Commuter Meaning/Metrics	Freight Meaning/Metrics
	associated with congestion pricing, high-occupancy toll (HOT) lanes, or no-drive policies on roadways; incentives for carpooling or using transit; or fuel costs.	receivers to alter staffing patterns, which may increase their costs.
Demographics	Though not a characteristic of the built environment, traveler demographics such as income, age, household size, employment, and other socioeconomic variables are important predictors of trip frequencies and VMT. Trip generation is a function of socioeconomic characteristics and the built environment. Therefore, demographic measures are typically used in travel studies to control for socioeconomic characteristics of human populations.	Hours of service (HOS) and workplace environment have become driving factors in the trucking industry. Many trucking firms have adopted regional market strategies that enable truck drivers to complete their routes in a single day (per HOS regulations) and return home each night.

One consideration for expanding this initial framework is to integrate the four-corridor owner/operator functions with the 7-Ds and explore the stakeholders required to implement significant change.

Table 2: D-Variables by Function and Important Stakeholders

Function	D variable	Commuter Stakeholders	Freight Stakeholders
Planning & Investment	Destination accessibility	General public, targeted populations, local governments	Shippers, service providers (all modes), econ development officials
	Distance to transit/alternatives	General public, targeted populations, local governments	Shippers, service providers (all modes), econ development officials
Design & Construction	Design	State county and local engineers, developers	State county and local engineers, developers

Function	D variable	Commuter Stakeholders	Freight Stakeholders
Ops & Maintenance	Demand Management	MPOs, local governments, tow truck companies	MPOs, local governments, tow truck companies
Regulation & Revenue	Density	City councils, county commissions, developers	City councils, county commissions, developers
	Diversity	City councils, county commissions, developers	City councils, county commissions, developers
	Demographics	Legislators,	Congress, FMCSA

2.7 Current Status of Methods, Measures, and Data

From the literature review, the following table represents traditional corridor management performance measures. Measures of congestion, reliability, pavement condition, and safety are the most common measures used to quantify the performance of transportation corridors. Economic impact and land-use performance measures are the least common.

Table 3: Literature Review Performance Measures

Category	Metrics	Reference
Operational performance	Transport service frequency	Wiegmans & Janic (2019)
	Size of deployed vehicle fleet	Wiegmans & Janic (2019)
	Technical productivity	Janic (2016), Wiegmans & Janic (2019)
Traffic Incident Management	Incident Responses (Number, type)	Abou-Senna et al. (2018)
	Incident (Duration, Response Time)	Abou-Senna et al. (2018)
	Average Incident Clearance Time	Abou-Senna et al. (2018)
	Number of Lanes Blocked, Closed	Abou-Senna et al. (2018)
	Rate/number of collisions	Abou-Senna et al. (2018)
	Rate/number of collisions (fatalities, injuries)	Abou-Senna et al. (2018)
Travel Time Reliability	Travel-Time Index	Abou-Senna et al. (2018), Mailer (2016)
	Planning Time Index	Pandey & Juri (2018), Abou-Senna et al. (2018)

Category	Metrics	Reference
	Buffer Time Index	Pandey & Juri (2018), Abou-Senna et al. (2018)
	On-time Performance	Pandey & Juri (2018), Abou-Senna et al. (2018)
Travel Time	Average Travel-time	Abou-Senna et al. (2018), Lee et al. (2019)
	Average Speed	Abou-Senna et al. (2018), Lee et al. (2019), Mbiydzenyuy (2018)
	Variance of Speed	Mbiydzenyuy (2018)
	Event Travel Time	Abou-Senna et al. (2018)
	Work zone speed reduction	Abou-Senna et al. (2018)
	Work Zone Lane Shifts	Abou-Senna et al. (2018)
	Transit time and Variation	Mbiydzenyuy (2018)
	Evacuation Time	Abou-Senna et al. (2018)
Multimodal approach	Light Passenger Vehicles (LPV)	Fernandes et al. (2017), Abou-Senna et al. (2018)
	Heavy-Duty Vehicles (HDV)	Fernandes et al. (2017), Abou-Senna et al. (2018)
	Freight volume	Abou-Senna et al. (2018), Mbiydzenyuy (2018)
	Travel times on key freight corridors	Abou-Senna et al. (2018)
	Transit Delay changes (%)	Abou-Senna et al. (2018), Lee et al. (2019)
	On-time Performance	Abou-Senna et al. (2018)
Transportation Demand Management	Congestion (Spatial, Temporal)	Abou-Senna et al. (2018), Mbiydzenyuy (2018)
	Volume per hour (Vehicle, person)	Abou-Senna et al. (2018)
	Vehicle class Distribution on Network	Abou-Senna et al. (2018), Mbiydzenyuy (2018)
	Delay (Event, Work Zone)	Abou-Senna et al. (2018)
Active Transportation Management (ATM) (ramp metering control)	Average trip travel time	Lee et al. (2019)
	Average trip delay	Lee et al. (2019)
Economic performance	Economic Impact Factor (EIF)	Dzumbira et al. (2017)
	Secondary Corridor Impact Factor (SCIF)	Dzumbira et al. (2017)
	Average costs of freight shipment(s)	Wiegmans & Janic (2019)
Environmental and social performance	Vehicle Miles Traveled	Abou-Senna et al. (2018)
	Vehicle Emissions (CO_2, CO, NOx, VOC)	Abou-Senna et al. (2018), Wiegmans & Janic (2019)
	Transit Vehicle Fuel Efficiency	Abou-Senna et al. (2018)

Category	Metrics	Reference
	Consumption (energy, fuel)	Wiegmans & Janic (2019)
	Cost of incident(accident)	Janic & Vleugel (2012), Wiegmans & Janic (2019)
Customer satisfaction	% of Pop. satisfied with travel conditions	Abou-Senna et al. (2018)
	Number, type of hits (app data, web)	Abou-Senna et al. (2018), Mbiydzenyuy (2018)
	Compliment Rate	Abou-Senna et al. (2018)
	Complaint Rate	Abou-Senna et al. (2018), Mbiydzenyuy (2018)
Corridor Infrastructure	Geographical Information	Lee et al. (2019)
	Chain length	Wiegmans & Janic (2019)
	Route length	Wiegmans & Janic (2019)
	Accessibility	Wiegmans & Janic (2019)
	Area coverage	Wiegmans & Janic (2019), Mbiydzenyuy (2018)
	Infrastructure density	Wiegmans & Janic (2019), Lee et al. (2019), Mbiydzenyuy (2018)
Dynamic Traffic Assignment (DTA)	DTA	Van Den Berg et al. (2004), Lee et al. (2019), Fernandes et al. (2017)
	Integrated DTA-RM	Lee et al. (2019),
	Mesoscopic DTA	Zhu et al. (2018)
	Integrated AgBM-DTA	Zhu et al. (2018), Lee et al. (2019)
	O-D matrices	Lee et al. (2019), Fernandes et al. (2017)

In addition to a literature review, the findings are based on existing practices (documented in Appendix 3 and Appendix 9) to determine the most common corridor objectives and associated performance measures.

2.7.1 Prominent Objectives: Improve Mobility and Safety

It is clear from the literature review in Appendix 1 and state of the practice exploration that the most prominent objectives of both federal and state DOT corridor management efforts are to provide roadway infrastructure for vehicular mobility that is as safe and uncongested as reasonably possible, while being sensitive to cost, context, and environmental stewardship.

But while these objectives are dominant, additional objectives are gaining consideration, such as the need for more and better alternative modes and the effects of speed-based objectives on expansive land-uses and carbon emissions. To the extent that more localized land-use directly within corridors has been considered, corridor management is usually a reaction to how land-uses have negatively impacted travel times and safety, and not a conscious effort to promote economic vitality or to catalyze development that increases use of alternative modes.

For mobility, the most common tool for assessing future congestion is a travel demand model, often coupled with a microsimulation model. But it is increasingly popular to use private Big Data sources such as Airsage or StreetLight to either improve travel demand and microsimulation models or instead of travel models, use

Big Data to extrapolate the future from the travel patterns of the present. Congestion is usually measured through a Volume/Capacity ratio (V/C), either at the link level in a travel model or intersection level with microsimulation models. Other common speed/congestion-related measures include changes in future speed relative to the present and vehicle hours traveled per capita relative to the present.

For safety, there is a strong focus on "Vision Zero," recognizing that while it will take a long time to get there, the goal is to see a day where no one will die in mobility-related accidents, and any injuries and property damage will be minimal. The most common approach for forecasting safety improvements is to obtain existing crash rates, usually as an average of recent years, then estimate a crash modification rate based on the design or management features being proposed. Expected improvements are often monetized based on federally approved values associated with injuries, fatalities, and property damage. Within the safety realm, there is increasing recognition of health problems associated with sedate lifestyles, and a desire to make it more attractive to travel by active modes (walking and biking) for the sake of improved public health.

2.7.2 Objective: Economic Benefits

A less common but increasingly important objective is focused on ensuring that transportation investments recognize multiple economic-related objectives. An important economic objective is effectively to reduce congestion and improve the speed of travel as already discussed. But more localized economic objectives are increasingly recognized, such as increased productivity, employment, business activity, income, property values, and tax revenues. Affordability is an increasingly important economic objective, which means that all residents can afford access to essential services and activities. Energy efficiency is also often considered an economic objective, which minimizes energy costs.

2.7.3 Objective: Improve Accessibility

There is a significant increase in accessibility as a measure to supplement or even replace speed/congestion-related measures. The purpose of improving speed or reducing congestion is ultimately to improve access to jobs, suppliers, education, and various goods and services. But speed of travel ignores that accessibility is fundamentally about both the average speed between origins and destinations, but also the average distance between them. Accessibility recognizes that even if speeds are reduced over a 30-year period due to congestion and other delays, the number of jobs and services one can reach in say a 30-minute timeframe can still increase if the average density and diversity of uses also increases during that time.

2.7.4 Objective: Livability/Walkability

Livability and walkability have historically been insignificant as a defined objective for corridor management, but recently many corridor studies and management efforts are siting improved livability and walkability as an objective. Measures of effectiveness often include Complete Street factors such as bike and pedestrian level of service, walk score, enclosure scores, as well as qualitative factors such as aesthetics, natural habitats, and community quality of life. Average parcel size, block size, and connectivity are also common measures.[59]

[59] "Get Your Walk Score," Walk Score, accessed October 26, 2021, https://www.walkscore.com/.

2.7.5 Objective: Sustainability

Sustainability is also a relatively recent corridor management objective, and it seems to include multiple objectives such as reducing human impacts on climate change through reduced carbon emissions, and also improving fiscal sustainability by accounting for life-cycle costs, and operational sustainability through plans that address how to leverage alternative modes and travel demand management, etc.

2.8 Conclusions and Gap Analysis

From the state of practice review and corridor studies and frameworks profiled for this report, a series of gaps are identified in the state of the transportation planning practice. At the same time, this review suggests there are considerable efforts being made to improve the state of the practice. The following sections explore these process gaps and offer potential solutions. The gaps and solutions are listed by planning step, but in practice, the gaps and potential solutions are interrelated and should be addressed comprehensively.

2.8.1 Gap: A Need for Acknowledging Trade-Offs

When there are many competing objectives, it is often true that to improve the performance of one objective, you must compromise on the performance of another objective. The task then is to locate solution sets that do a good job in all categories, rather than a perfect job in one category at the expense of other categories. There appears to be no standard framework for discovering a wide range of objectives across multiple types of stakeholders, then weighting those objectives and measuring expected performance in each objective so that a comprehensive corridor management plan with broad support can emerge.

2.8.2 Gap: Long-Range Planning

Metropolitan and statewide planning requirements focus on the development of long-range transportation plans. This makes sense. Looking into the future, projecting travel demand, estimating transportation network deficiencies, developing project lists, establishing a reasonable financial plan, and in areas with air quality issues, implementing mitigation efforts to meet federal and local air quality standards is a good business practice.

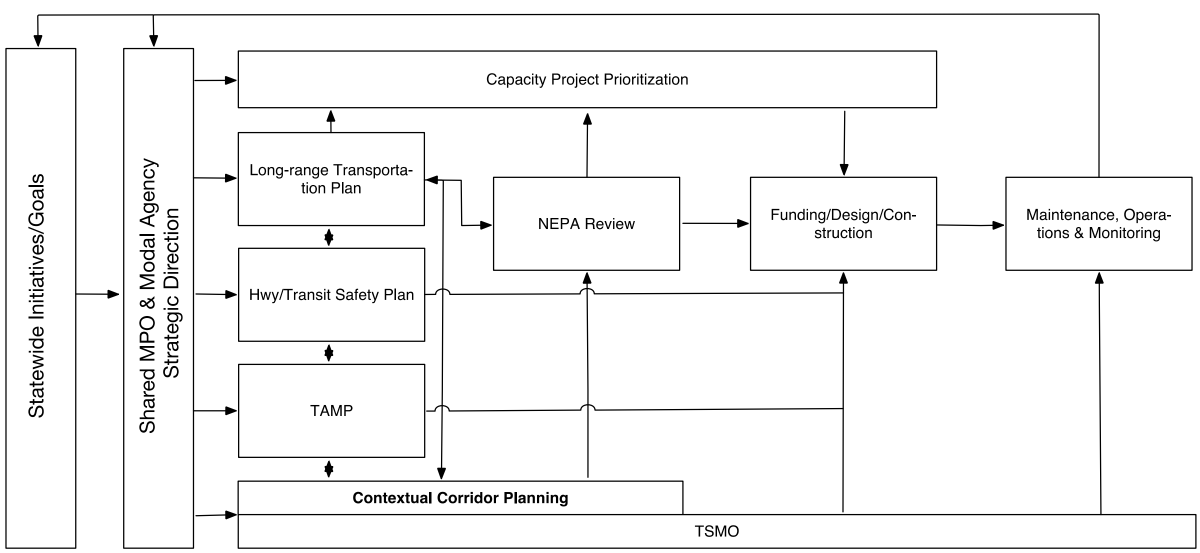
Project-based plans help states and regions understand the scope of transportation improvements needed to meet future travel demand, and the projected financial resources required to meet that demand. Ideally, once identified, the financial needs will culminate in a comprehensive funding strategy that includes federal, state, and development-driven funding mechanisms. Observations made in the corridor innovation database in Appendix 9 as well as the body of case research in Appendix 3, demonstrate that metropolitan and statewide planning requirements are important and serve as a best practice. The relevant question for this effort is not whether long-range planning is important. Rather, it is whether projects developed in the long-range planning process should be taken at face value.

Purpose of long-range plan projects: Projects shown in long-range plans are suggestions of a way to address increasing demand. They are not usually well-vetted, and thus implementing agencies such as DOTs and transit agencies should not assume projects on the long-range plan represent ideal solutions. The scope and scale of long-range planning and its primary tool, travel demand models, do not lend themselves to the development of detailed corridor solutions. A review of practice shows that solutions take into consideration a broad range of contextual issues important at sub-regional and local levels, which are difficult, if not impossible to understand in long-range planning.

Long-range planning is the first step in project and solution development. In practice, however, there can be a disconnect between planning and project implementation, especially metropolitan long-range planning. By considering downstream requirements, planners can structure their processes to deliver relevant and necessary products to subsequent steps.

With respect to the interrelationship between processes, it should also be noted that some projects in long-range plans may come from corridor planning activities and thus represent longer-term contextually based solutions. When this happens, these projects should be considered differently than projects developed using long-range planning tools; processes are not always linear and sequential.

To resolve this, practitioners can acknowledge the strengths and limitations of current long-range planning practices; establishing needs versus developing contextually based corridor solutions and delivering the next phase of the project development process with a product that can be used and not redone. The following flowchart demonstrates the interdependencies of strategic direction, planning, preservation, safety, NEPA review, project delivery, monitoring and measuring, and feeding those results back into the beginning of the process.



Source: Metro Analytics; 2020

Figure 23 Solution Development Process

Expectations: Inter and even intra-agency expectations can be very different. With respect to inter-agency differences, state DOTs, transit agencies, and MPOs answers to different governing structures have different constituents and can have different missions, visions, goals, and objectives. These differences can lead to a lack of strategic focus, poor agency relationships, disjointed implementation, and public and political dissatisfaction.

With respect to DOT intra-agency differences, the aspirational outcomes of planners are not always understood, or fully appreciated by implementers. Planners are tasked with thinking about multiple long-term objectives including transportation, land-uses, economic and quality of life outcomes. Engineers on the frontlines of project implementation, especially in a high-growth area, can see the world very differently. They are often confronted with significant public and political pressure to relieve congestion, improve safety, and improve reliability. An environment where short-term realities can conflict with long-term aspirational outcomes.

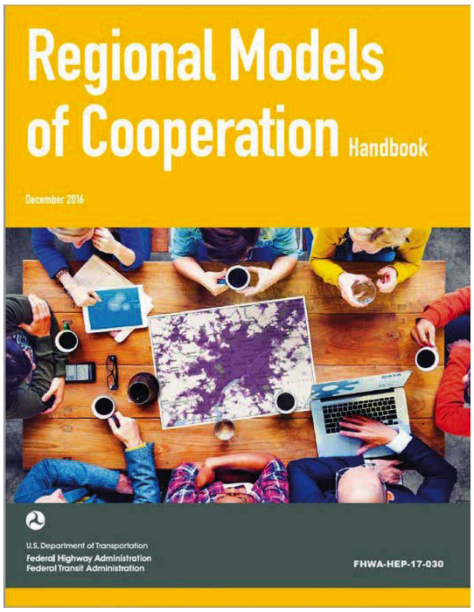


Figure 8 Solution Development Process

The literature review, corridor planning profiles, and documented experience in Appendix 3 and Appendix 9 reveal that partnering and collaboration are key. Sustained collaboration and partnering can improve strategic alignment, resulting in better planning and project implementation. It leads to better solutions, cheaper implementation costs, and credibility. An example is Utah's unified transportation planning process. In Utah, agencies have shared statewide initiatives and transportation network goals based on agreed-upon community, economic, and quality of life objectives. Utah's unified transportation planning process has generated significant political and public credibility and has resulted in the willingness of state and local government leaders to fund transit, roadway expansion, active transportation, and preservation needs. Utah, a red state, currently commits approximately 17-19%, or about $825M, of annual state sales taxes to transportation system capacity improvements, including allocations for transit and active transportation. The Utah legislature has fully funded Utah DOT's preservation needs with gas tax increases; implementing one of the nation's first indexed state gas tax systems. Local governments have also implemented local-option sales taxes to fund transit, roadway capacity improvements, and preservation needs.

Planning During Times of Rapid Change: The state of the long-range planning practice is largely based on knowledge and understanding of the past and using this knowledge to make point forecasts about the future. Traditional planning considers possible futures, envisions a preferred future, and sets goals for land-use and transportation improvements to meet those desired outcomes. Given the type and rate of change, and its potential for broad societal impacts, the old planning paradigm will struggle to meet agency needs in the medium and long term.

Numerous efforts are underway to better inform and provide tools necessary to plan during these times of rapid and disruptive change such as *NCHRP 20-102 (19)B: Impacts of AV/CV on State and Local Transportation Agencies*, an AASHTO established AV/CV subcommittee, and the FHWA recently published *Automated Vehicle Modeling.*

Peer Exchange, was a TPCB Peer Exchange Event in which they developed guidance on AV/CV scenario planning guidance. A concept emerging from these efforts is exploratory planning. Exploratory planning helps agencies develop tactics to help plan for and react to changes. It considers multiple, possible trajectories of change and evaluates risks and opportunities based on these trajectories. These efforts are also helping agencies explore and understand the range of issues that could be affected by the adoption of AV/CV technologies.

2.8.3 Gap: Performance-Based Planning and Programming (PBP&P)

Based on a review of practice and available guidelines (such as the FHWA guide shown to the right) the implementation of PBP&P has been a major step forward in transportation performance management. It is listed as a planning gap because of the to-date focus on national performance measures and reporting rather than the value derived from the process of establishing goals, objectives, and performance measures.

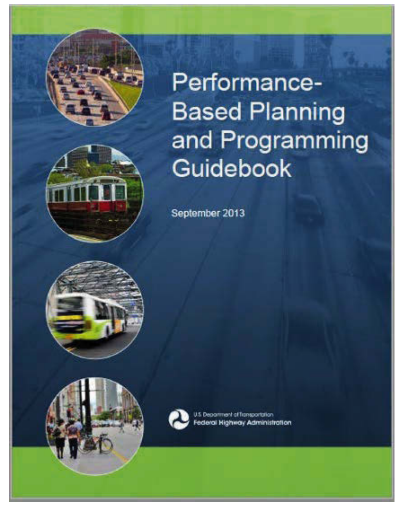


Figure 9 FHWA Performance-Based Planning and Programming Guidebook

As discussed earlier, inter and intra-agency collaboration and partnering in establishing shared goals, objectives, and performance measures can improve relationships, align values, and improve transportation agency relationships and credibility with political leadership and the public. With two years of performance measure reporting perhaps it's time to shift the discussion to the importance of developing shared goals, objectives, and performance measures.

2.8.4 Gap: Joint Transportation/Land-Use Visioning

Many areas have used, and are using, "visioning" as means to foster dialogue and improve understanding of the interrelationships between transportation improvements, land-use changes, economic activity, jobs, housing, and quality of life. Visioning can play a significant role in improving the understanding of the complexities of creating livable communities with improved quality of life outcomes. Regional visioning has improved understanding of these issues among policy and political leaders and to some extent the larger public.

Where visioning sometimes breaks down is in implementation. It's easy for political leaders and the public to state a preference for sustainable land-use developments and shifts away from SOV use and toward transit and active transportation. However, revealed preferences are often very different. At the same time, it's relatively easy for MPO boards, usually comprised of mayors, to approve aspirational regional land-use and transportation visions that would create 7-D intensive activity centers. But local land-use decisions are made by planning commissions and city councils, which can face considerable public opposition to such initiatives. So, how does industry improve the implementation of visioning efforts?

An intriguing example of a program addressing this issue head-on is the Wasatch Front Regional Council's (WFRC) "Transportation and Land-use Connection" (TLC) program. WFRC is Utah's largest MPO covering the Salt Lake and Ogden-Clearfield MSAs.

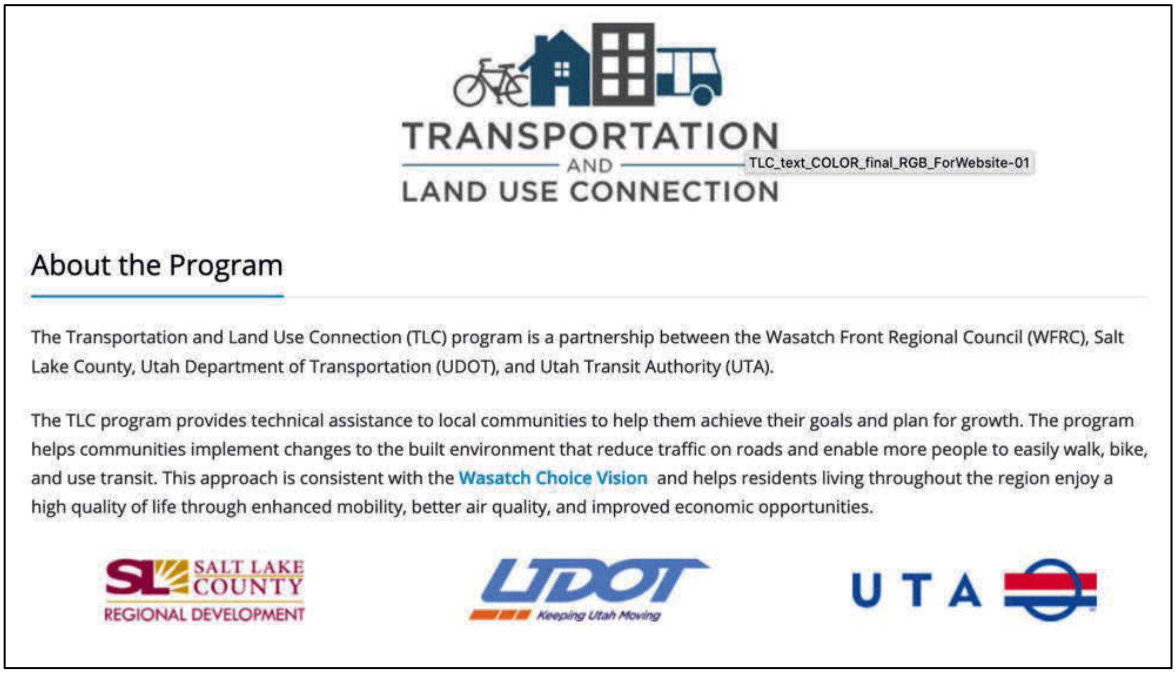


Figure 10 Wasatch Front Regional Council wfrc.org/programs/transportation-land-use-connection/

As stated on the TLC website, "The program helps communities implement changes to the built environment that reduce traffic on roads and enable more people to easily walk, bike, and use transit."[60] The TLC program is built around local government and public inclusion. Local governments must apply for TLC funding and demonstrate how their proposed projects support and further WFRC's 2050 land-use plan of creating strong multimodal activity centers and walkable transit-oriented boulevards.

The program receives about $1.5 million in annual funding, which along with a modest required local match results in $1.8 million annually. TLC funding is provided by WFRC, the Utah DOT, and Salt Lake County. The success of the TLC program has spawned additional planning grant efforts. The state of Utah has initiated a similar statewide planning grant program. Local governments must apply and show how their projects will advance statewide land-use, economic and transportation objectives. Both of these efforts directly link visioning, planning, both long-range and corridor planning, with project development and implementation outcomes.

2.8.5 Gap: Corridor Planning

Corridor planning is not new. DOT's, MPO's and local governments have long used corridor studies to assess corridor improvements. The literature review and profiled corridor studies, however, suggest there is no clear definition of what constitutes a corridor study, how one should be conducted, or even what should be assessed beyond traditional metrics like safety, access management, congestion, delay, and reliability.

Inconsistent Application and Definitions of Corridor Planning: The body of case research in Appendix 3, as well as the database in Appendix 9, demonstrates that inconsistencies in the application of corridor planning is partially the result of no formal federal requirement for corridor planning. To ensure compliance with

60 "Transportation and Land Use Connection," Wasatch Front Regional Council, accessed October 26, 2021, https://wfrc.org/programs/transportation-land-use-connection/.

federal requirements for long-range planning, NEPA, and project development activities transportation agencies have developed formal workflows geared to those requirements. Essentially, corridor planning, with its many derivations, has been used as a situational remedy.

The closest that the observations of practice in Appendix 1, Appendix 3, or Appendix 9 come to an intermediate planning requirement was the short-lived Major Investment Study requirements of ISTEA and TEA 21, and FTA's use of alternatives analyses. Consistent interpretation of these requirements within an agency or corridor management program can greatly aid in the development of impact-based corridor management.

Planning and Environmental Linkages (PEL): PEL could be a powerful tool to help improve the efficacy of planning. Yet, its application remains elusive, even for DOTs with full NEPA assignments. The net effect is that much of the work completed in planning must be redone in NEPA. That decreases the efficacy and credibility of planning processes and frustrates the public who end up feeling like all their previous work and expectations are thrown away once NEPA starts. Implementation of a consistent framework for defining corridors and organizing coalitions (as shown in Play 1: Define the Corridor and Its Impact and Play 3: Build Durable Coalitions and Processes) can address a previous lack of formal corridor planning frameworks associated with this unfortunate outcome.

In summary, there are three paths articulated in the planning regulations that allow for the products of the planning process to be used in the initiation of NEPA. Agencies can establish preliminary purpose and need, eliminate unreasonable alternatives, and begin the evaluation of reasonable alternatives while in the planning phases of project development. To do so, however, planning processes must be rigorous and meet federal requirements.

2.8.6 Gap: Stratified Return on Investment

Return on investment has long been a mechanism for decision making, and usually estimates the monetizable return to a specific stakeholder based on the investment that stakeholder makes in the corridor. As described previously, the recently published *NCHRP 917: Right-Sizing Transportation Investments: A Guidebook for Planning and Programming* describes a "stratified ROI" methodology that may be helpful in corridor management. The goal is to bring together multiple stakeholders and discover their general goals and objectives within a corridor, or the "return" they hope to get from a project and policy solution set. Return in this sense may not be easily monetizable, but the group will attempt to monetize it for the sake of comparison. The stratified process then seeks to identify how important each goal is to the overall group of stakeholders (a weighting mechanism) and seeks agreement on the measures that will be used to quantify how well an alternative solution set performs with regard to the various goals.

The investment part of a stratified ROI includes the overall investment required to obtain that return, and the sources of that investment, which might include non-traditional contributors such as a business improvement district. In addition to initial capital cost, the investment denominator can also include lifecycle, and user costs, as well as intangible contributions from stakeholders.

A good process also recognizes that there is component ROI. For example, a "Transit-heavy Alternative" might include a very expensive light-rail line but could also include relatively low-cost investments in bus-stop amenities and better connectivity to adjacent neighborhoods. It may be discovered through the process that the rail portion of the alternative while gaining a lot of transit riders, is very expensive relative to the number of riders gained. Better bus stops may not gain many riders, but in terms of riders gained per dollar spent, it may be a better investment than rail, and thereby warrant inclusion in a preferred solution set, even if the rail portion is dropped. As with right-sizing, a corridor management framework will likely require stratifying and recognizing the different needs and expectations of beneficiaries when assessing corridor impacts.

2.8.7 Gap: Explore the Role of Corridor Management in Induced Demand

It is clear there is a significant opportunity to explore how traditional vehicular mobility objectives have shaped land-use patterns, and how alternative corridor management strategies could help foster alternative land-use patterns, to the extent that corridor stakeholders desire such alternative patterns. It is worth exploring the effect that higher-speed corridors such as freeways and limited access arterials tend to have on land-use patterns. With the pending advent of automated and connected vehicles, there is a strong chance of inadvertently catalyzing land development patterns that are even more expansive than in the past if people are willing to spend more time in travel because they can be more productive than at present. If so, these trends could create low-density development pressures that are contrary to many community, region, and statewide objectives. The speed-based linkage to land-uses needs to be well understood and accounted for in corridor management efforts.

Corridor management policies often aim to reduce travel times for existing travelers, but that often inadvertently induces new VMT per capita as when new residents adopt far-flung lifestyles even further into the fringes, but otherwise would have made shorter origin-destination decisions. Induced demand is a well-documented phenomenon.[61] Many researchers believe that within as soon as 3 to10-years, VMT that otherwise would have been less will instead expand to fill all of the new capacity. An interesting question is whether some kind of congestion pricing strategy across all lanes of an urban freeway could potentially help catalyze 7-D VMT-reducing land-uses in Brownfields and Greyfields that need revitalization.

2.8.8 Gap: Life-Cycle Fiscal and Operational Sustainability

The state of the practice has little consideration of a proposed project's fiscal and operational sustainability when viewed over multiple life cycles, especially for "Big Dig" type projects, where increasingly higher costs per lane-mile can start to outweigh benefits. This is especially true when considering induced demand, which could eventually lead to a potentially unsustainable number of additional people and businesses being auto-dependent or dependent on potentially fragile systems. When a management strategy will result in an unsustainable number of vehicles becoming dependent on a single corridor, it raises questions about right-sizing and resiliency. Should the mix of modes and mode incentives in the corridor be altered to improve resiliency? Would a right-sizing exercise help identify opportunities to reduce auto dependency? What is the next generation, or the next decade, supposed to do when an even "Bigger Dig" is needed due to unaccounted for but reasonably predictable induced demand? When reconstruction becomes necessary,

[61] Susan Handy and Marlon G. Boarnet, "Impact of Highway Capacity and Induced Travel on Passenger ...," September 30, 2014, https://ww2.arb.ca.gov/sites/default/files/2020-06/Impact_of_Highway_Capacity_and_Induced_Travel_on_Passenger_Vehicle_Use_and_Greenhouse_Gas_Emissions_Policy_Brief.pdf; Ronald T. Milam et al., "Closing the Induced Vehicle Travel Gap between Research and Practice," Transportation Research Record: Journal of the Transportation Research Board 2653, no. 1 (2017): pp. 10-16, https://doi.org/10.3141/2653-02; Gilles Duranton and Matthew A. Turner, "Urban Growth and Transportation," Urban Growth and Transportation 79, no. 4 (2012): pp. 1407-1440, https://doi.org/10.1093/restud/rds010.

can they affordably replace what is falling apart around them while they attempt to maintain huge levels of traffic at the same time?

2.9 Emerging Frameworks for Planning and Measuring Corridor Performance

The opening sentence of the RFP commissioning the NCHRP Corridor Management Playbook effort states, "The integration of transportation planning and land-use is critical to ensuring sustainable corridor functionality and surrounding growth." The ideal just described is reflective of the challenge in achieving sustainable functionality while promoting sustainable growth. This stems in part from the definition of "sustainable functionality." From the literature review in Appendix 1 and corridor profiles of current corridor planning practice, it is clear that state DOTs are focused on maximizing corridor speed and vehicle throughput, within a tolerable level of safety for all modes of travel. The literature review and profiles also suggest there is increased demand for alternative modes of travel and livable places. The following section outlines some promising examples of best practices in corridor planning and corridor management.

From the literature review and corridor study profiles completed for this effort, it's apparent that industry experts have recognized the need to strengthen corridor planning processes as means of better integrating land-use and transportation decisions. Indeed, a number of agencies have made corridor planning a formal part of their planning and project/solutions development workflows.

An excellent example of an agency tool recognizing the intercedence of the project development processes is FHWA's PlanWorks website.[62] The main feature of PlanWorks, a SHRP2 product, is four decision guides detailing the decisions made in long-range planning, corridor planning, NEPA review, and programming. PlanWorks also has several applications and tools that can help MPOs, DOTs, and transit agencies navigate the interrelationship made in these processes. Other agency examples include Arizona DOT's Complete Transportation GuidebookUtah DOT's Solutions Development Process, Denver Regional Council of Governments' Planning Framework, Montana DOT's Transplan process, and CalTrans corridor planning framework.[63]

There are other examples of transportation agencies and states broadening their view of transportation corridors. TxDOT for example uses a Transportation Reinvestment Zone Program to help fund transportation improvement; cities, counties, and port authorities are eligible for the program.[64] While primarily a funding mechanism, this program recognizes the importance of transportation corridors in catalyzing economic activity and growth. In the TxDOT example, local governing bodies designates a zone in which it will promote a transportation project.

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[62] US Department of Transportation, "US Department of Transportation," Welcome - PlanWorks | Federal Highway Administration, accessed October 26, 2021, https://fhwaapps.fhwa.dot.gov/planworks/.
[63] State of California, "Corridor Planning," Corridor Planning | Caltrans, accessed October 26, 2021, https://dot.ca.gov/programs/transportation-planning/multi-modal-system-planning/system-planning/corridor-planning; "Complete Transportation Guidebook," Complete Transportation Guidebook | ADOT, accessed October 26, 2021, https://azdot.gov/planning/transportation-programs/complete-transportation-guidebook; "Intermediate Planning," Corridor planning, accessed October 26, 2021, https://maps.udot.utah.gov/wadocuments/Apps/planning/; "Metro Vision," Metro Vision, accessed October 26, 2021, https://metrovision.drcog.org/; "Montana Department of Transportation," TranPlanMT, accessed October 26, 2021, https://www.mdt.mt.gov/tranplan/.
[64] Texas DOT, Transportation Reinvestment Zone, accessed October 26, 2021, https://www.txdot.gov/government/programs/trz.html.

FHWA in collaboration with Appleton, Wisconsin conducted a pilot study to improve health outcomes in the College Avenue corridor (FHWA-HEP-16-028). The corridor study was intended to provide a vision for what a multimodal corridor could be in the future and to identify the potential health implications of various alternatives. The modes of transportation considered include vehicles, transit, freight, and bicycle and pedestrian.[65] FHWA has also developed a Health in Transportation Corridor Planning Framework.[66] The aim is to support transportation agency efforts to incorporate health into corridor planning studies. It is intended to be used within an existing corridor planning process, not as a stand-alone or parallel process. Because transportation planning at the corridor level is flexible and adaptable to many different issues and contexts, the Framework is scalable to any type of corridor.

Figure 11 Health in Transportation Corridor Planning Framework

Florida's ICE program requires that for anything other than minor resurfacing or signal timing adjustments, each significant intersection in the corridor should explore the feasibility of all known traditional and alternative intersection operational strategies.[67] Those that at first glance appear potentially feasible are then further explored. The FDOT ICE manual states, "The goal of ICE is to better inform the FDOT's decision-making to identify and select a control strategy meeting the project's purpose and need, fitting the intersection location's context classification, providing safe travel facilities for all road users, and reflecting the overall best value."

Such a program opens the door to a wider set of objectives, where stakeholders define the goals and performance measures by which best value will be determined. While the overall speed of travel and ability to reduce delay will always be an important measure and perhaps the most heavily weighted measure, the framework allows stakeholders to introduce additional goals and measures and weight them according to their perception of best value. The program is also intriguing because it is one of the first to formally mandate that corridor management efforts explore a wide array of intersection treatment options, to avoid

[65] US DOT FHWA, "Testing the Health in Transportation Corridor Planning Framework in Appleton, Wisconsin," U.S. Department of Transportation/Federal Highway Administration, November 30, 2015, https://www.fhwa.dot.gov/planning/health_in_transportation/planning_framework/framework_test_cases/appleton/case_study/index.cfm.
[66] US DOT FHWA, "Health in Transportation Corridor Planning Framework," U.S. Department of Transportation/Federal Highway Administration, May 23, 2017, https://www.fhwa.dot.gov/planning/health_in_transportation/planning_framework/the_framework/index.cfm.
[67] "Intersection Operations and Safety," FDOT, accessed October 26, 2021, https://www.fdot.gov/traffic/trafficservices/intersection-operations.shtm.

situations where a better design was available, but stakeholders were not aware of it or didn't vet it appropriately.

2.9.1 Contextually-Based Corridor Planning, Management, and Performance

As stated previously, transportation agencies have long used corridor planning to assess corridor level improvements. Increasingly, transportation agencies are recognizing the need to broaden the issues they consider when establishing corridor and transportation network goals, objectives and performance measures. Funding constraints; state, regional, and global economic considerations; changing values; quality of life considerations; natural and aesthetics outcomes; access to jobs, services, and recreational opportunities; and health outcomes are a sampling of issues transportation agencies are being asked to consider when planning, prioritizing and programming transportation projects/solutions.

To this point, in the appendix, the terms "projects" and "solutions" have been used somewhat synonymously. Given the range of issues transportation agencies are being asked to consider, it's increasingly necessary for these agencies to think in terms of solution-sets. Clearly, projects are solutions, but a solution-set is a set of interdependent initiatives crafted to address a complex set of desired outcomes. A contextually based corridor planning process can help agencies accomplish this.

2.9.2 The 7-D Framework

Based on research presented in Appendix 3, Appendix 10, and Appendix 11, the 7D Framework is a model for establishing a contextually based corridor planning process. The 7-D Framework is a method to help transportation agencies and stakeholders think about the assessment of transportation corridors. Traditionally, agencies have focused on transportation metrics when assessing corridor improvements. The 7-D Framework allows for a broader contextual understanding of corridors and systems of corridors. A broad contextual understanding lends itself to non-traditional goals, objectives, and performance measures. The findings of both the literature review in Appendix 1 as well as the case research in Appendix 3 and the database of practices in Appendix 9 suggest that contextually based corridor studies will help improve corridor level person and freight throughput while also helping achieve community, natural environment and health outcomes. While the literature review and the corridor studies profiled for this effort did not specifically identify the 7-D Framework, it's clear from the review that many of the 7-D Framework elements are being used in the evaluation of corridor improvements. But again, without a formal contextually based corridor planning framework, the application of non-traditional performance measures will be hap hazard.

2.9.3 Corridor Optimization and Big Data

Optimization modeling is just one area of advanced analytics that is growing in use in both private and public sectors. Often misused as a term of reference for any process that seeks to identify the best solution, optimization modeling is a mathematical approach to finding the best solution using linear programming applied to big data. Private sector freight service providers and shippers have used mathematical optimization for decades to improve efficiency and reduce costs. Examples include the Class I railroads who used optimization models in the wake of deregulation to rationalize their networks and improve profitability.

Trucking fleets use network optimization to determine where terminals should be located based on customer demand and operating costs associated with fuel and driver wages. Shippers use optimization to make facility location decisions that result in the lowest cost supply chain network. In a recent iteration of an annual survey of third-party logistics (3PL) services conducted by Penn State University, 39 percent of shippers indicated that network modeling and optimization were capabilities they looked for in 3PL providers, and 62 percent of responding 3PLs said they offer those capabilities.

Transportation agencies also use network optimization tools to improve the operation of networks. Such tools include traditional micro simulation tools, which are expensive and difficult to develop and typically relegated to use in high-volume corridors. More and more transportation agencies are using probes, Bluetooth sensors, in-pavement sensors, and eventually real-time data from in-vehicle infotainment sets to assess corridor performance. For example, agencies are using real-time data to assess red-light arrival and vehicle platooning. From the data, these agencies can determine if corridor performance is degraded by poor signal optimization.

Optimizing corridor operations is a key to improving transportation network performance. Another value of optimization tools and big data is the measurement and monitoring component of PBP&P. These optimization tools and the use of real-time big data are key in assessing the outcomes of solutions developed in contextually based corridor planning and refining the knowledge and assumptions used in the planning process.

2.10 Summary

The objective of this state of the practice report is to document the current state of corridor performance impact analysis and to discuss elements for enhanced planning and corridor management frameworks. In addition to a literature review, Appendix 9 documents a series of corridor studies, corridor management programs, and other current practices related to corridor planning and management. While there are inconsistencies and gaps in current corridor management practices, there is growing recognition in the industry for a consistent process that will result in improved corridor performance.

Appendix 3

Case Research and SWOT

3.1 Executive Summary

This appendix documents the body of case research supporting the Playbook on Corridor Management. The report is the last in a series of exploratory reports exploring the 2021 state of the practice for evaluating corridor management impacts and implementing consistent and innovative plays for managing corridors. This report builds on previous literature review (APP 1) and state of the practice report (APP 2), providing (1) a framing of corridor impacts addressing the wide range of corridor management contexts, (2) a comprehensive body of case research on different types of corridor management impact assessment techniques and their role in corridor management processes at all levels throughout the United States and (3) a critical review of strengths, weaknesses, opportunities and threats (SWOT) associated with the current state of the practice, and resulting specification for the corridor management framework.

Overview and Rationale

Corridor impact assessments are understood as nested local, inter-regional and national impacts within the context of large corridor systems. The case research makes observations in relation to (1) high-level national and inter-city trade functions that are addressed by state and multistate coalitions, (2) regional and inter-regional relationships to specific trade centers, local economies and supportive arterial and tributary systems and (3) local systems of land-use, economic development, livability and competing uses which can greatly affect the ability of the overall system at the capillary level to serve the conflicting requirements of users. The high-level corridor systems and sub-systems are nested into four national-level systems which are observed both in national terms, inter-regional terms and within specific communities through the lens of metropolitan trade centers served by the corridors, as shown in Exhibit 1.

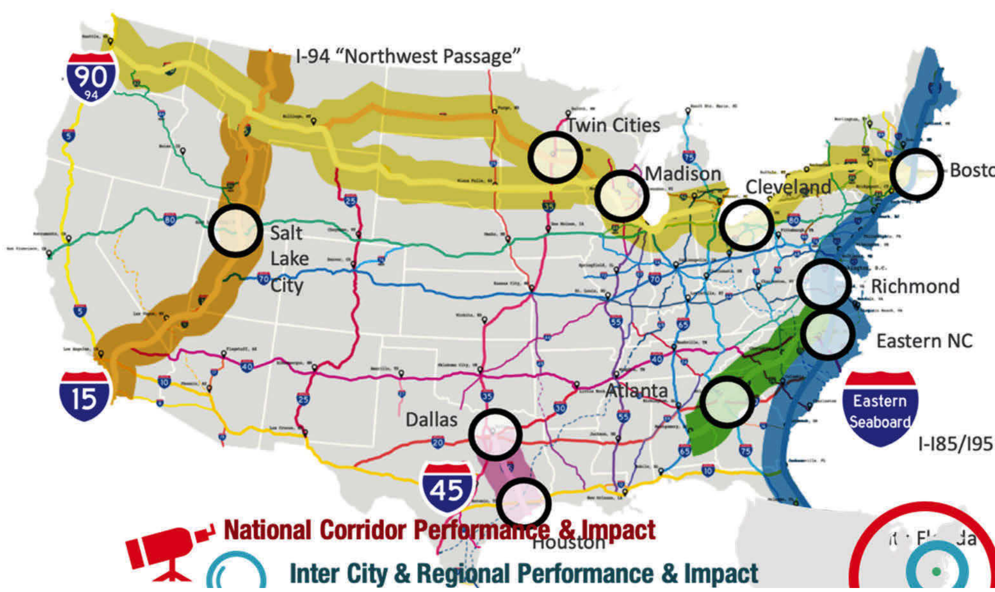


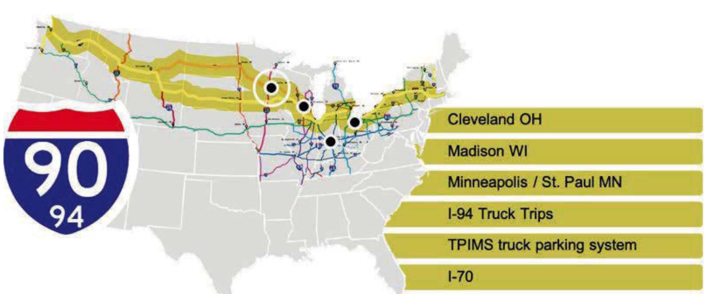
Exhibit 1 Corridors Studied

Key dimensions of evaluation, informed by Appendix 1 and Appendix 2 include key factors such as (1) the use of appropriate impact methods for different levels of scale and complexity of corridor definition (2) the balance of supply and demand-side indicators regarding corridor performance and management techniques, (3) the appropriate use of ex-ante predictions, benchmarking observations and ex-post evaluation techniques at key junctures throughout the management process and (4) the integration of authority, intelligence and resources available through corridor coalitions. Additional considerations framing the assessment include (1) measuring the impacts of corridor management on Autonomous, Connected Electric and Shared (ACES) vehicle technologies and models (2) methodologies used to assess the overall impacts of strategies and (3) the sufficiency and validity of data currently used in measuring the impacts of corridor management. Corridor impact assessment approaches are understood both for each corridor system as a whole as well as for particular inter-regional or local areas within the systems.

Impact for Corridor Systems and Sub-Systems

Corridor impact strategies are profiled across four national systems with their associated tributary (inter-regional) and capillary (local/regional) impact markets/networks across all modes . The four systems featured include (1) the I-90/94 system across the northern US, (2) the I-95/85 system across the eastern US, (3) the I-45 Inter-Regional System in Texas and (4) the I-15 Inter-Regional System in the southwest US. As a contrast to the I-90/94 system, selected observations are also made regarding the I-70 system in Missouri.

3.1.1 I-90/94 System Review



The I-90/I-94 System is characterized by a host of multistate corridor coalitions, which have been formed to address different aspects of the corridor's performance across different states and multistate regions. These include coalitions addressing diverse modes of transportation including (1) the Great Northern Corridor (BNSF) rail line and its multimodal points, (2) the North/West Passage coalition focusing on ITS deployment, (3) the Smart Belt Coalition with a strong focus on autonomous/connected technologies, the I-94 West Corridor Coalition in Minnesota focusing strongly on business and government collaboration to enhance the corridor business environment and the Gary-Chicago-Milwaukee Corridor Coalition Legacy – focusing largely on traffic operations.

Specific observations in Cleveland, Ohio, Madison, Wisconsin, Minneapolis/St. Paul, MN, I-94's trucking management and the TPIMS truck parking system highlight a broad range of management strategies for specific elements of the corridor ecosystem and how their impacts are quantified. The review finds a wide range of land-use, livability, freight, incident management, operational and economic impacts observed at different levels. Some of the key observations for the system include:

Corridor Management Means Different Things to Different People (Practitioners): The in-depth research conducted for the I-90/94 corridor only confirms and strengthens that observation. This I-90/94 case study investigation found an eclectic mix of coalitions from neighborhood coalitions like Rondo, to public/private partnerships like the Great Northern Corridor and I-94 West Corridor Coalition, to the ITS operations coalition of the North/West Passage. Each coalition expressed different perspectives of what corridor management means, applying different types of impact indicators and methods.

Communication is a Common Theme in Corridor Management Strategies: While understanding that corridor management depends on your perspective – communication is a common thread throughout all management strategies; for example:

- The Great Northern Corridor focused on communicating the economic benefits of a multimodal corridor to political leaders and businesses in the corridor to build a foundation for increased investment in corridor infrastructure.
- The Northwest Passage and Great Lakes Region Traffic Operations Coalition have focused on communicating traffic and travel information to users of the system. Communicating information and data between coalition partners in real-time or near real-time is also a central tenant of coalition activities.
- Due to the I-94 West Coalition, MnDOT' Metro District undertook a study to identify commercial users of the corridor that should be informed during construction in the corridor. The value of freight expenditures made by private businesses was also communicated to senior management and politicians to help educate policymakers about the need to keep commerce flowing.
- Finally, the Re-Thinking I-94 Project sought to re-establish communications with a neighborhood devastated by past poor land-use decisions. The underlying purpose of the study was to open communication and build trust to prevent poor decisions from reoccurring in the future.

In effect, the audiences for corridor management impact assessments have largely driven the types of indicators used. A key finding is that corridor management impact measurement is as much about audience-driven communication as it is about objective analytical rigor.

Corridors Do Not Operate in a Vacuum:

The quotation to the right, from an interview regarding the Gary, Chicago, Milwaukee Corridor Coalition captures the challenge of assessing and communicating corridor impacts, given the decentralized policy environment in which national corridors operate. A central challenge for the Next Generation Corridor Framework relates to how large coalitions like those serving the I-90/94 system will be able to meaningfully assess, communicate and leverage the wide range of performance areas needed to effectively support corridor performance.

> *"How do we as a nation with a weak federal model operate an extremely valuable national resource, the interstate system; and, at the same time incorporate technologies and monitor operations?... It is an easier task in China or the European Union which utilizes a strong, top-down approach to coordinate policy and action. What is the institutional model for sustaining commitment amongst shareholders moving forward for collaborative state-based management of the national road network beginning with the interstate system? What should the federal government's, state agencies', and local jurisdictions' role be?*
>
> - John Corbin (FHWA) on the history of the Gary, Chicago, Milwaukee Corridor Coalition

The Lack of an On-going Funding Mechanism for Multijurisdictional Corridor Coalitions Hinders On-going Monitoring: Some of the early corridor management efforts examined in the I-90/94 corridor have either dissolved or have been re-formulated for different purposes over time. Some of the coalition representatives discussed data collection activities for their own internal purposes, but few or none were undertaking data collection activities on a multi-jurisdictional basis. The GNC initiated corridor-wide metrics, but when MCOM funding was lost, all available resources have focused on infrastructure investment. NWP collects data and pushes out information to corridor users to support its mission: *The vision of the North/West Passage Corridor is to focus on developing effective methods for sharing, coordinating, and integrating traveler information and operational activities across state and provincial borders.*[68]

3.1.2 I-95/85 System Review

The I85/95 System is characterized by a few major corridor coalitions and initiatives, such as the Eastern Seaboard Corridor Coalition, the Downeaster Rail line (managed by AMTRAK but with supportive planning in communities all up and down I-95 between Portland, Maine and Boston), intra-state coalitions led by DOTs and MPO's in Massachusetts, Virginia, North Carolina, Georgia and Florida. The corridor is also rich with corridor management impact measurement or quantification attempts, including complex MPO planning efforts in places like Boston, MA, the Atlanta Regional Commission in Georgia, the MPO in Richmond Virginia and Florida DOT's 4th district. There are also significant observations of rural and largely undeveloped areas, for example, I-95 where NCDOT has explored the funding and performance challenges of a corridor that is largely pass-through for North Carolina – but economically significant to the nation – as well as the 15-501 tributary system (supporting I-85 access for both Durham and Chapel Hill, NC in a rapidly evolving urban development context. Exhibit 1 Corridor Management Impact Areas illustrates several corridor management impact areas, and which are observed in relation to each different area studies in the I-95/85 System.

Exhibit 1 Corridor Management Impact Areas

TOPIC	GEOGRAPHY								
	Down Easter	Boston MA	Corr. N PA	Richmond VA	I-95 Corr. Coalition	I-95 NC	15-501 NC	Atlanta GA	SE FL
Truck Parking				●	●			●	
Commercial Vehicle Lanes							●	●	
Planning & Environmental Linkage (PEL)	●		●		●	●		●	
Identification of Smart Corridor System					●			●	
Public-Facing Open Data & Dashboards	●	●	●	●	●			●	●

68 North/West Passage, "North/West Passage Updated Focus Areas, Issues, Vision, Goals and Objectives," North/West Passage, May 7, 2019, https://www.nwpassage.info/about/strategicplan/.

Corridor Management - Hazardous Incidents (Hurricanes, Snowstorms, etc.)	●			●	●	●			●
Connected Vehicles (CV)/Integrated Corridor Management (ITS)				●	●			●	
Performance Measures	●	●	●	●	●	●	●	●	●

Major takeaways from the Eastern Seaboard case study include several ways to measure performance within a corridor ranging from operational performance, incident management, commercial vehicles and connected and autonomous vehicles. While each state and/or MPO may measure their corridors differently, they are following federal guidelines and identifying additional measures to meet the needs of their area. Overall, there are some opportunities to coordinate on performance measures which could open an opportunity for states to discuss how to disseminate.

3.1.3 I-45 Inter-Regional Corridor in Texas

The I-45 Corridor, while not actively managed by coalitions at any level, is the subject of active collaboration between Texas DOT (TxDOT), the MPO's in Houston and Dallas, Texas and the Texas Central Railway. It provides significant examples of how the impacts of an inter-regional corridor between two major rapidly growing trade centers can be managed within the same state.

Management Without Formal Coalitions: As a relatively short corridor that exists entirely within Texas, the TECC is unique in many ways. Management of the corridor might be less complicated since the entire corridor is overseen by TxDOT. Because interstate coordination is not required, TxDOT can make decisions for the corridor without considering the priorities and needs of other states. The corridor's short length also provides fewer potential partners for multijurisdictional coalitions. To some degree, however the collaboration between TxDOT, the Houston and Dallas MPOs and the Texas Central Railway function as a de-facto coalition.

Infrastructure Supply and Travel Demand Management Tactics and Impacts: With population growing rapidly along the corridor, particularly in the Dallas and Houston areas, many opportunities exist to coordinate land-use and transportation. New, denser housing will likely be necessary to support growth, and the I-45 corridor should evolve to meet these needs. With traffic congestion already a major concern in Dallas and Houston, transit options along the corridor (likely running along frontage roads) may help to ease future strains on the roadway without spending time and resources expanding the freeway itself. High-quality transit options along I-45 would also likely lead to transit-oriented development, which can bring about diversification of land-use that enables people to live closer to jobs and amenities, further reducing strain on the roadway network. Houston, in particular, seems to be heading towards more pro-active demand management with its proposal to limit the expansion of the I-45 right of way in north Houston, and instead focus on transit and active transportation investments. Dallas also considers transit, but in a more limited way that would mostly serve people commuting from residential areas closer to central Dallas to the multimodal freight hub in south Dallas County.

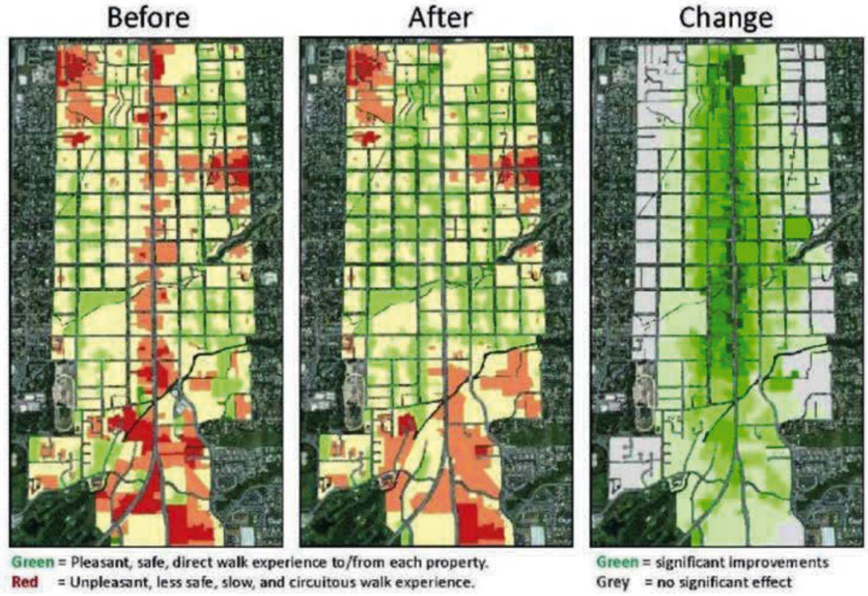
Passenger Multimodal Strategies: The Texas Central Railway also promises to give Texans an additional mode choice for travel between Dallas and Houston. The TECC overall serves a region experiencing great economic success and high population growth, and the corridor represents a chance for the state of Texas and two of its largest metropolitan regions to work together to reimagine how a modern corridor can function and be managed with longevity in mind to provide equitable transportation options for all stakeholders.

Measurement of Impacts: In effect, the partners on I-45 have focused either on traditional measures of VMT, VHT congestion, delay, safety and air quality consistent with MPO and DOT targets – without the use of the exquisite dashboards used elsewhere. However, the strong focus on both passenger and freight multimodal solution sets – especially involving inter-modal rail and transit planning, combined with new growth management policies make the region a very strong candidate for the testing of 7-D report cards and benchmarks for using demographic, destination access, modal diversity and other "D-variable" considerations.

3.1.4 I-15 Inter-Regional Corridor from Canada to California

The I-15 Corridor System while running all the way from Canada to California, is actively managed from Utah to California. Active coalitions observed in its management include (1) Logan City Main Street Partnership in Logan, Utah (demonstrating how a tributary system to I-15 can have significant effects on a community's ability to benefit from its inter-city access, but also balance with local growth considerations (2) the I-15 Mobility Alliance in the Salt Lake City region of Utah (demonstrating innovative corridor management impacts in the face of significant environmental and spatial constraints) and the Alameda Transportation Authority (highlighting the complexity of connecting a major global port to a corridor system through ancillary facilities in a complex urban growth and traffic environment.

Exhibit 2 ViaCity Walkability Index



Main Street/Logan: The I-15 corridor is instructive in a number of respects. The Logan example demonstrates how a walkability index can provide a practical assessment for assessing a corridor's "walkability" when considering corridor alternatives. The "ViaCity" index in Exhibit 2 is easily replicable when a city is an active partner in managing a corridor, bringing available information about bicycle and pedestrian infrastructure and traffic operations. The reality of Logan's main street is connecting its two major tributary routes to the I-15 system (US 90 and State Route 30) in association with its role as an economic asset to the community.

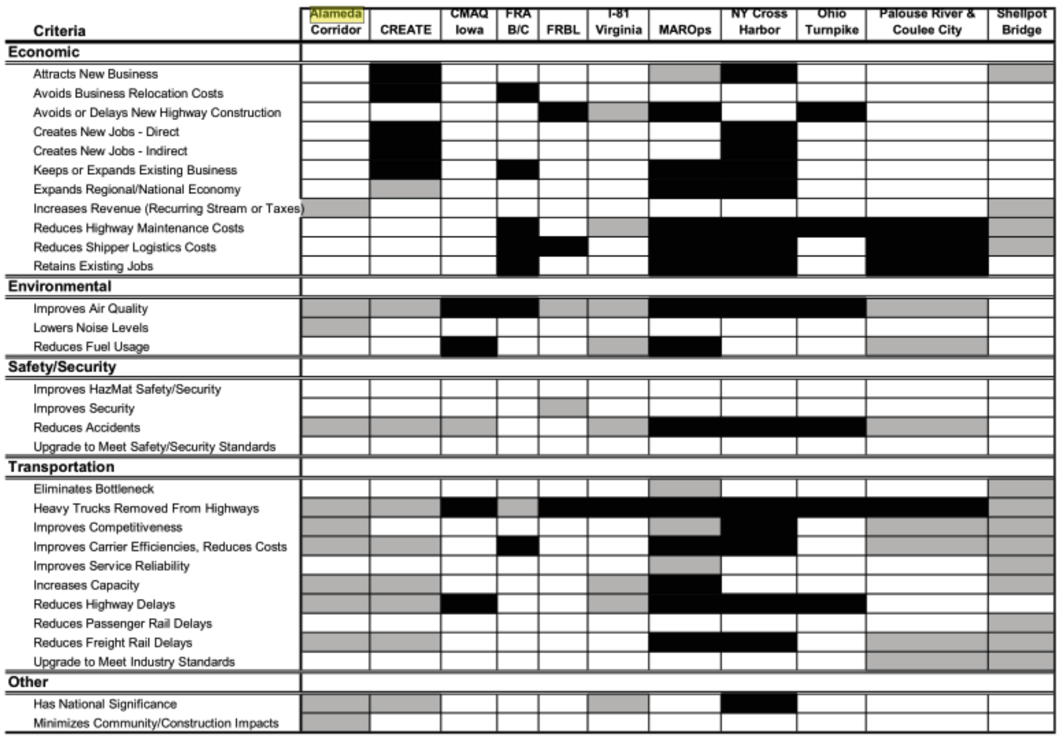
Metropolitan Salt Lake Region: There are several lessons learned from the regional management of the I-15 system in the Salt Lake City Region. The region is moving toward the adoption of more comprehensive corridor management performance metrics The regions MPOs, WFRC and MAG, have progressive land-use planning processes; Wasatch Choice for 2050 is a land-use vision that underpins their respective RTPs; MAG, WFRC and UDOT have also implemented a real estate market model that is used to iterate land-use and transportation responses as well as using the model to allocate pop and employment to TAZ structure. The region still manages corridors in a relatively isolated manner, and they have not adopted, at the operational level, the more comprehensive metrics used to develop their long-range plans and corridor studies. The area does have experience with corridor coalitions, but they tend to develop organically, based on individual corridor contexts. UDOT has implemented a comprehensive corridor/intermediate planning corridor planning process that does have a process that could help build corridor coalitions.

The state's unified transportation planning process is robust. The partners have synchronized planning cycles; they share a joint financial model and assumptions; they develop shared goals, objectives and performance measures across plans; and they have a policy board consisting of agency leadership and board that coordinate activities. Given the small number of MPOs and unique culture of Utah, it's not clear how much of this structure is directly transferable to other states and regions. Utah is also unique in that most of UDOT's capacity projects are funded with auto-related sales taxes, which make up approximately 17% of all sales taxes generated in the State of Utah.

Alameda Corridor: The Alameda Corridor is instructive because (1) it illustrates how much can be assessed about a corridor strategy through a wide range of passenger and freight impact metrics and (2) it illustrates how differently evaluations of corridor impacts can come out – depending on the framework for assessment. Many of Alameda's impact assessments suggest that success in managing the Alameda Corridor appears more favorable if the framework considers the management effort less in terms of managing freight traffic than in terms of improving automobile connectivity, and quality of life for communities along the rail line. Exhibit 4 above (from *NCHRP 08-36, Task 43 Return on Investment on Freight Rail Capacity Improvement*) demonstrates that despite the freight rationale for Alameda – the impact measurement efforts have been overwhelmingly qualitative – and have focused more on mobility than economic or trade considerations.

Exhibit 3 Alameda Corridor Quantitative/Qualitative Analysis

Quantitative Analysis – Black Shading, Qualitative Analysis – Gray Shading



Findings Within Larger Corridor Management Context

The body of case research documented in this SWOT offers a window into how corridor entities are using data and measures to assess the impacts of both corridor performance and evaluate the potential impacts of strategies. It is notable that there were few if any instances of comprehensive sets of corridor management impacts applied at the national system level, and such impact sets were largely inconsistent between metropolitan areas within national corridor systems. It is also notable that while promising examples can be shown of a wide array of impact metrics, both with respect to land-use/transportation "D-Variables" and higher-level inter-city goods movement and capacity factors – the measures are seldom applied together for a strategically balanced view of corridor impacts. When reflecting on the state of the practice from this SWOT review of corridor impact methods – it is also striking that there is no coordination between those local coalitions and entities and the state, inter-city, or national coalitions, which often operate in isolation from one another.

The case research answers important questions about what it will take to offer an impact framework that will (1) significantly enhance the use of corridor impact metrics, (2) achieve balanced supply- and demand-side strategies, (3) understand impacts at key junctures in the corridor management process and (4) combine intelligence, resources and authorities as described in Chapter 2.2. This chapter of the SWOT focuses strongly on key elements of the framework that can address holistic observations about the requirements for a Next Generation Corridor Framework that integrates the wider 7-D approaches described in Appendix 2. These elements can be grouped into five framework categories supported by observations in the SWOT:

Scale and Geography: The review of corridor system impact practices offers insights into the need for scalable measures to different types of corridors and geographies, while still managing them as part of the same system and strategy. The case research above shows a range of corridor sizes and geographic areas and how they might assess impact differently.

Alignment with Role: In most of the case observations – the view of impacts resulted from a focus on what the corridor managing entities could do in terms of jurisdiction and what the corridor stakeholders had the authority to do that is important to consider when determining an impact assessment framework. This points to the need for a framework that is flexible for use by those with different levels of authority and jurisdiction – possibly associating particular impact areas with particular jurisdictional roles. The framework should also recognize and highlight, the limitations on the authority of the varied public-agency corridor stakeholders. This information is helpful to ensure a clear understanding of enforcement and follow-up responsibilities by stakeholders to evaluate the long-term success of the corridor management goals.

Comprehensive Time-series Measurement: Most of the observations in the case research revealed that corridor entities often do their most comprehensive assessment of impacts within the context of planning studies for the subject corridors, but they were mostly a snapshot-in-time. There were only a few examples of entities that had routine benchmarking or ex-post measurement to determine impacts or monitor performance as described in Chapter 2.2. Most of the routine analytics had to do with Intelligent Transportation System (ITS) operations. Additionally, the case studies showed heavy reliance on mobility and safety measures, which is consistent with the literature review. It did not reveal the use of a holistic suite of impact areas to round out the type of information needed to determine impacts from a variety of angles such as land-use and stakeholder perception.

Data Governance and Organization: The case studies illustrated a range of data sources and measurement methods. They demonstrated a need for a framework to help provide some standards - methods for data organization and governance, industry-tested and approved measurement methods and data sharing and collaboration opportunities.

Coordination and Communication: An important element for success in corridor management appears to be coordination and institutional organization. There are roles for state Departments of Transportation (DOTs), Metropolitan Planning Organizations (MPOs), cities, counties and other stakeholders. Some of the case studies demonstrated organizational plans and routines that appeared to help in the operations of the corridor. Additionally, there is a growing use of communications tools and dashboards to disseminate information.

Conclusions and Next Steps

In addition to the findings regarding the structure and use of a Next Generation Corridor Framework, some general specifications regarding the characteristics of the framework in relation to impacts related to freight movement, land-use/sustainability, mobility performance, economic role and impact, data sufficiency and technology. Some Next Generation Corridor Framework specifications suggested by the SWOT include:

Freight: The findings suggest the framework should offer an interpretation of “7-D” variables in both the urban and inter-city freight context, with associated roles for local, inter-regional and national partnerships. The framework should include a guide to widely accepted data for making these considerations practical to apply to freight at inter-city and local levels.

Land-use/Sustainability and Community Resilience: Findings point to the need for a framework offering an appropriate level for addressing land-use and sustainability in the corridor management process, with roles for entities best suited to contribute land-use solutions. The framework will have to be structured to demonstrate the impact measures that can be evaluated and tracked at different levels. Inputs, procedures and outputs for such analyses will need to be demonstrated. Building on existing practice as observed in the current report, - these may range from dashboards and models to simple self-assessment check-lists, building from the practices and needs observed in the case research. The findings also point to a need for the framework to suggest an appropriate relationship between local management efforts at the city or neighborhood level and larger national and inter-regional strategies.

Mobility Performance Measures: Findings show that while mobility performance is the most common and widely considered area of impact – a framework will have to address the issue of standardizing mobility and performance measures based on the practices of management partners (as opposed to one-time top-down studies). Current practice shows the framework will need to provide a way for considering linkages between state and MPO targets and corridor-wide targets at national, state and local levels. In the same way, the framework will have to consider the role of the Federal performance measures in relation to the underlying diversity and rationale of local and regional measures.

Economic Role/Impact of Corridors: The state of the practice shows that while economic impact models and indicators are applied – such outcomes still need to be associated with funding opportunities in a holistic understanding of value on a corridor. To meet this gap in practice, the framework is envisioned as a platform to consider impact payoffs and investment resources at all levels of public and private corridor management (not just state DOT cash flows).

Data Sufficiency: The state of the practice shows that there are far more methods available for using data than there are data consistently available at the appropriate levels and junctures in corridor management. For example, tools like ViaCity (as observed in the Logan case) can be widely applied, in as much as municipal and state entities are sharing data to support it. Likewise, there are very exquisite dashboards in use in many jurisdictions that can balance freight and passenger needs – however such efforts cannot support the right ex-post, ex-ante and benchmarking needs of effective corridor management unless appropriate sources, roles and standards are in place for working coalitions. For this reason, the case research points to the need for the framework to offer guidance regarding the level of granularity and consistency for corridor impact intelligence at different levels. The framework is also envisioned to demonstrate how data from corridor management partners can be leveraged within a 7-D context to support targets for managers at all levels. As a starting place, the framework is likely to be able to meet the gap at the most essential level by supporting practical self-assessments for corridor managers to evaluate and incrementally improve the consistency and effectiveness of their use impact data utilization across corridor systems.

Technology: The state of the practice shows that while corridor managers are extremely effective in leveraging and applying technologies – they often do not have context for benchmarking or evaluating what impact (if any) the role or use of technology is having on long-term outcomes. For example, corridor managers did not generally have a baseline for assessing their technological sophistication or readiness, or incremental next steps with regard to emerging or disruptive technology, In this way the case research supports the need for a framework that offers roles and opportunities to assess the status of corridors with respect to emerging or disruptive technologies Such a framework can also be responsive to the state of the practice inasmuch as it is conducive to goal setting at national, regional and local levels for both technological readiness and incremental implementation of technological advances.

3.2 SWOT Overview & Rationale

The goal of this Strengths, Weaknesses Opportunities and Threats (SWOT) case-study analysis is to critically evaluate how well the impact measurement practices for managing corridors balance the tradeoffs between community development and regional trade in support of wider corridor management efforts. Several case examples document (1) the current role that impact assessments play in the estimated success of different corridor management strategies in relation to (2) the effectiveness with which studies and other efforts have quantified this impact.

The Playbook is based on a review of corridors through both a sampling of metropolitan areas in the US as well as non-metropolitan and regional settings to assess a broad range of corridor management efforts. Cases are selected to represent corridors operating at different levels of scale and complexity (including national, regional, inter-regional and local corridors) as well corridors where stakeholders have sought to quantify impacts using a diversity of available economic and other performance models and methods such as cost/benefit analysis, economic impact models (such as REMI and TREDIS), multi-criteria indexes (which combine and weight different types of impacts).

The review is intended to provide a critical case-by-case examination of the most comprehensive and widely understood corridor impact efforts to date. Examples of potential new online and collaborative GIS applications or dashboards are also documented. The source material for the SWOT analysis includes a content analysis of published plans and documents to map out the main stakeholders and strategies used in the region's corridor management efforts as well as interviews with agencies directly involved in the corridor management efforts. The SWOT provides examples of how existing evaluation techniques represent the interests of different types of stakeholders including public agencies, community groups, supply chain managers, environmental interests, developers, and others described in the introduction to the approach.

Defining Corridors and Characteristics

A key requirement of the SWOT analysis has been to structure a general mechanism by which a corridor's length and width boundaries are defined. From a comprehensive review of corridor management efforts and strategies, Playbook is based on a nested approach for the purposes of reporting the SWOT (though not for the final research product). The case research offers the SWOT through a representative assessment of major national corridor systems, which have (1) high-level national and inter-city trade functions that are addressed by state and multistate coalitions, (2) regional and interregional relationships to specific trade centers, local economies and supportive arterial and capillary systems and (3) local systems of land-use, economic development, livability and competing uses which can greatly affect the ability of the overall system to serve the conflicting requirements of users. This presentation of corridor impact practices will lend itself to further consideration with respect to the 7-D variables and other factors in subsequent deliverables.

Assessing Impact Methodologies

This report is intended to provide a holistic and critical assessment of existing practices for quantifying the impacts of corridor management strategies:

(1) Critically describe the ways that corridors have been defined by corridor management efforts to date
(2) The methods that have typically been followed in late 20th century and early 21st-century corridor management impact reporting and measurement regimes
(3) The data that have typically supported corridor management impact analysis, and
(4) How these elements have been combined into corridor management impact frameworks in the past.

More importantly, the Corridor Impacts State of the Practice report includes (in APP2) - a framework/gap analysis

(1) Highlighting opportunities to make the process of defining corridors more meaningful within the context of corridor management objectives and
(2) Suggesting how the programmatic steps and use of impact metrics in corridor management can be enhanced using recent research and data
(3) Consider how 21st-century data sources that can be integrated into a 21st-century corridor impact framework (and how they can be applied), and
(4) Suggest next steps in the evolution of corridor management in light of these findings.

National Corridor Systems and Sub-Systems

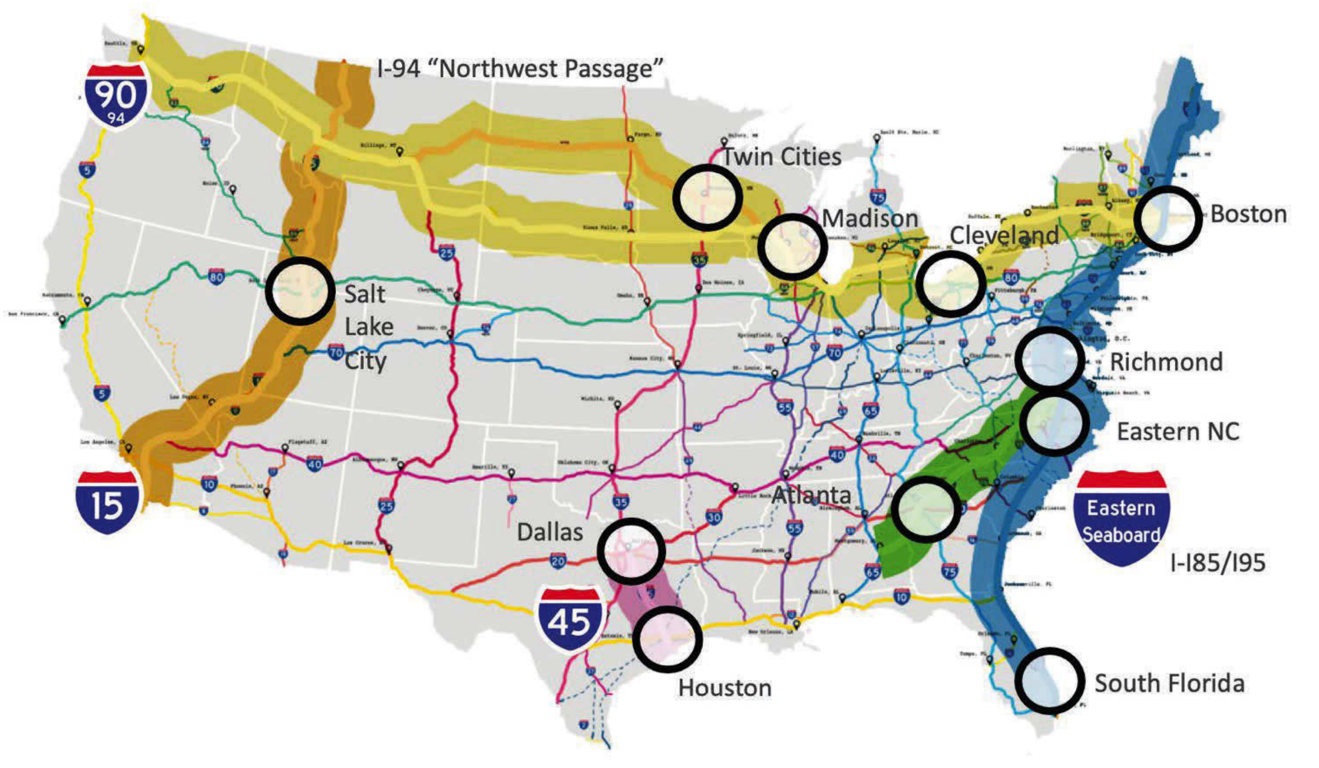
While it is not possible to inventory every corridor management effort or impact measurement approach in the nation – the case research for the Playbook focuses on four major national corridor systems. These corridor systems are understood not to be limited to the highway facility for which they are named, but are understood as ecosystems of trade centers, communities, primary and secondary roadways, and other modal systems. By nesting its observations in this way – analysis is able to assess strategies at the national, inter-regional, and local levels – and to consider how even communities far away from interstate highway right-of-way may have supply chains, downtowns, business clusters, streets and other components to be considered with respect to corridor management.

This organization of systems and sub-systems is also chosen as it mirrors the way in which corridors are actually managed – where there are coalitions at the multistate, inter-regional, local, and in some cases even neighborhood level. One observation is that there are often coalitions within coalitions (where a corridor may be managed by a multistate coalition, but then within a particular city may have a section concurrently managed by a local coalition, often focusing on different aspects of performance. This arrangement of the SWOT allows us to document the role that impact measures play at each of these levels, evaluate not only the data and methods (which are found not to be very complex) - but also the junctures in corridor management where they are or are not applied – and where a Next Generation Corridor Framework can make a significant contribution.

3.2.1 Impact Measures and Management by Coalitions

Exhibit 4 below demonstrates four national corridor systems chosen for a qualitative review of corridor impact measurement practices. These include north-south as well as east-west corridors across multiple states, including localized focus areas in seven metropolitan areas as well as significant rural, forested, and suburban areas across the nation. Each of the four national corridor systems featured has a multistate or inter-regional coalition that serves as a starting point for the review, and then opens up into specific inter-regional and local management and impact assessments that are featured within the context of the broader system. Source material includes a review of published corridor studies and benchmarking reports and websites, as well as depth-interviews with coalition members, DOT staff, and MPO staff in related areas. Selected observations are also taken from corridor environments outside of these corridors where such observations may demonstrate dynamics or highly pertinent examples of existing practice, which were not documented within the four large corridor systems.

Exhibit 4 National Corridor Systems Studied



3.2.2 Critical Aspects of Evaluating Corridor Impact

Each corridor system's impact regime is understood in terms of five critical focus areas derived from both the research objectives and the reviews Shown in Appendix 2. Each focus area is included from national, inter-regional, and local perspectives. These focus areas include:

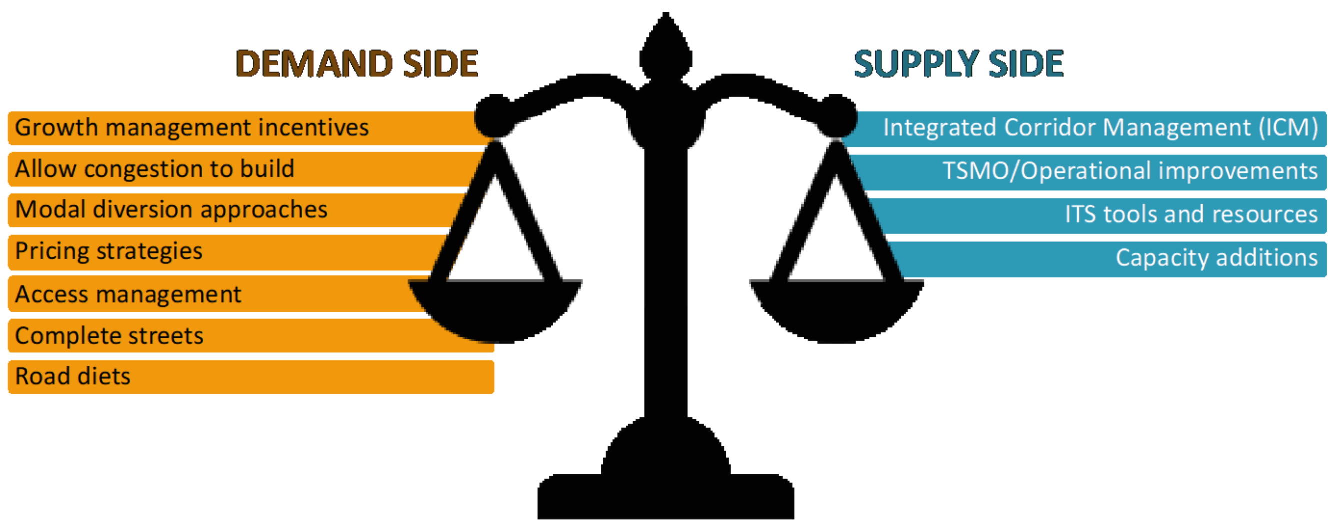
Corridor definition and characteristics

Observations are made regarding how different groups managing each corridor system define the extent of their management activity and the scope of impact that is of interest. As previously stated, these definitions may not even include area within the right of way of the interstate facility or facilities of the national corridor "ecosystem" but may also include definitions of street systems, neighborhoods, local economies, or supply chains that have been of concern when assessing the outcomes of the wider system. For example, the nested observations include areas such as downtown, Logan Utah (an arterial which also shares a "main street" function, but is dependent on the community's ability to utilize I-15, many miles away), the Amtrak Downeaster which shares a passenger inter-city travel market with the I-95/85 system between Boston and Portland, Maine and the Rondo Neighborhood of St. Paul where a minority community's quality of life and economic trajectory was forever altered by the location of an interstate highway. The SWOT seeks to critically evaluate what can be learned by the geographic and socio-economic scope of corridor impact management efforts to date, to serve as the foundation for understanding in subsequent reports **"where and how can we better define the scope of corridor management impacts in future decisions".**

Corridor management strategies

While the Playbook is not offered so that practitioners can devise entirely new management strategies, it is

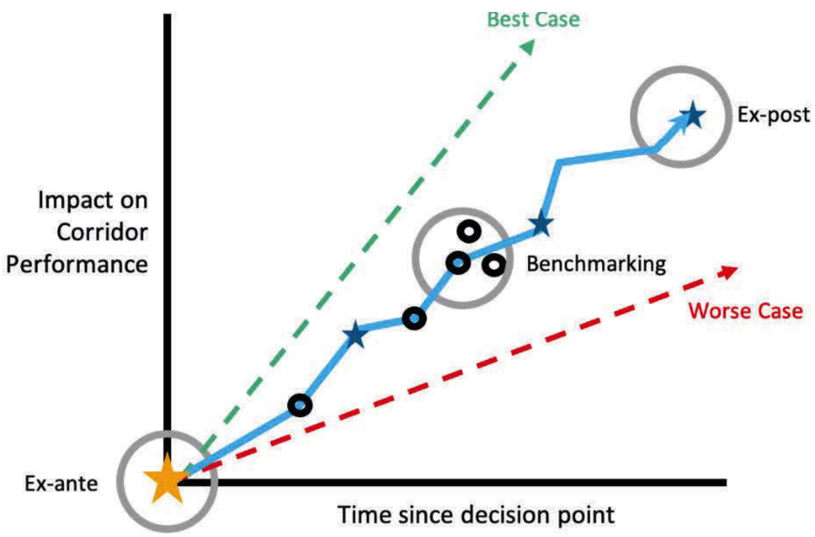
Exhibit 5 Supply and Demand-side Tactics and Impacts



understood that impact frameworks must be evaluated within the context of larger strategies. For this reason, the SWOT includes specific observations about the strategies in place, and how effectively they do or do not utilize available measures. This report is constrained by the fact that it can only observe those strategies that are actually in place (and Appendix 5 explores new and emerging quantification techniques).

Supply and Demand-Side Tactics and Impacts: Given the 7-D orientation of the wider research approach of the Playbook – specific attention is given to the balance of supply-side strategies (focusing on capacity and infrastructure) and demand-side strategies (focusing on demand management, locational or logistic efficiency or user behavior). There is also significant attention given to the junctures in the corridor management process where impacts are even considered. (For example, are impacts only considered at a forecasting/ex-ante stage of management, are they benchmarked throughout the process, and are they ever considered in an ex-post evaluation context?).

Exhibit 6 **Ex-Post, Ex-Ante and Present-Time Measures**



Ex-ante, Benchmarking, Present-Time, and Ex-Ante Junctures: Exhibit 7 demonstrates how in the life of a corridor, there are different decision points (represented by stars). At the outset (yellow star), ex-ante measures may seek to estimate expected management impacts (between best and worst cases).

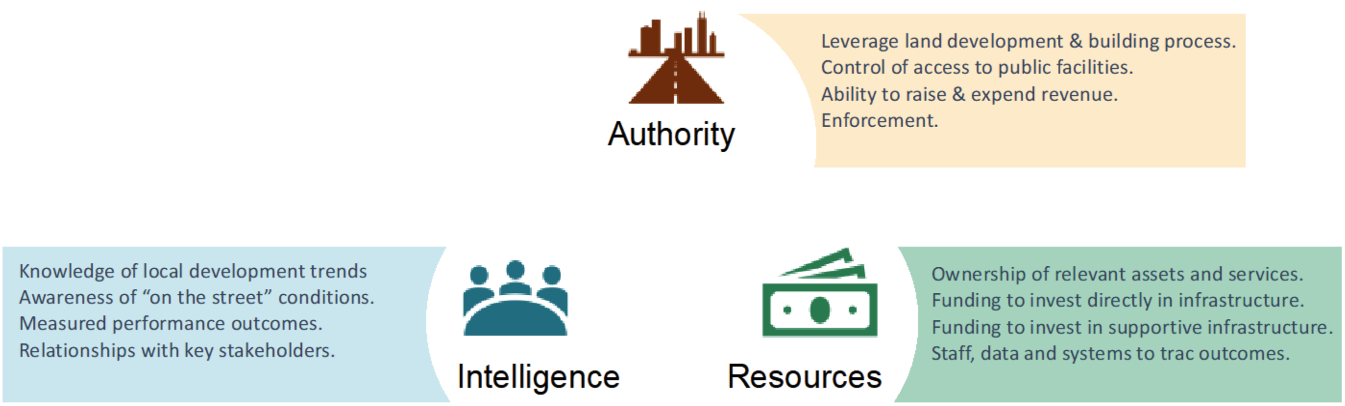
As the strategy is implemented, actual (present or benchmarking) impacts may be observed at certain data points (represented by circles), supporting incremental decision points (represented by blue stars).

Over time, the managers can reflect (ex-post) both on the impact of corridor performance before, and since the management effort was undertaken. Understanding the state of the practice for how consistently or adeptly impacts are considered at these junctures in corridor management is a key consideration in this SWOT for the state of the practice.

Authority, Intelligence, and Resources: The SWOT recognizes that when modeling impacts at any given decision point (star), there can be a rich body of research supporting scenario planning methods. Such data and methods can enable corridor managers to achieve a one-time observation, forecast, or trend assessment for impact variables that may be more difficult to benchmark or monitor through the ongoing life of the corridor management process. For example, a coalition may perform an expensive corridor study updated every 5 years, treating each 5-year update as a "decision point" (shown on the diagram as a star) for calibrating the overall management effort. Yet between updates or studies – when funding is more scarce -- the universe of impact measures that managers can use to track performance on an ongoing basis is much smaller than the universe they may include in a one-time or periodic study. Also, the universe of measures that corridor managers can model or estimate (inferring from other data) is likely much larger than what they can really observe as performance is actually occurring (or even afterward). The SWOT is very intentional in considering observations of how corridor managers look at performance at ex-ante, ex-post – and as on-going benchmark junctures.

When observing strategies, the SWOT also takes into account how effectively coalitions managing corridors (at all levels) utilize the collaborative nature of the corridor coalition to share authority, intelligence, and resources. *NCHRP Synthesis 337: Cooperative Agreements for Corridor Management (2004)* describes the rationale for the management-by-coalition model that has been adopted for many corridors. Effectively, when corridor treatments are limited only to those which can be controlled by a single agency (such as a DOT which can readily control capacity and geometrics) – the understanding of impact and performance becomes limited to those things the agency can control and measure (speed, crash rate or delay). By contrast, the cooperative agreements that characterize corridor management seek to bring other partners to the table, who can measure more impacts, and who have the authority to leverage a wider range of supply and demand-side strategies. Exhibit 7 from *NCHRP 917*: Right-Sizing Transportation Investments (2020) illustrates this principle as a Venn diagram, in which the multi-agency management process is intended to facilitate sharing of authority, intelligence (information and analytical capacity), and resources (money, property, and other things) not available from any one agency. The SWOT explores the degree to which corridor coalitions effectively leverage (or fail to leverage) this type of collaboration to expand the effectiveness of performance outcomes to date.

Exhibit 7 Strategic Dynamics



Source: *NCHRP 917*

The strategic dynamics of (1) balancing supply and demand-side tactics, (2) selecting the junctures in the corridor management process to consider impacts, and (3) the appropriate use of coalitions to combine authority, intelligence, or resources are understood to largely determine how impacts can be understood. For this reason, the SWOT seeks to critically evaluate the question **"how effectively do existing corridor management strategies utilize impact measurement through the corridor management process?"**

ACES (Autonomous, Connected, Electrical and Shared)

Increasingly, states and metropolitan areas are interested in tracking their progress in both their readiness and effective use of autonomous, connected, electrical and shared vehicle business models and technologies. The SWOT explicitly explored such strategies, and their utility to date in the corridors observed. While there are no impacts or principles in place for all of the corridors, where there are approaches they are assessed. In the performance of the corridor management effort in making such technologies available (or their status in implementation) is often more of a measure than the actual performance outcomes to date. The SWOT seeks to address **"how is the impact of corridor management on the technological progress and readiness of corridors currently understood in the experience of corridor management?"**

Methodologies to assess strategies

At the outset, it was anticipated that the SWOT would profile (in detail) the impact methods applied to corridors in a step-by-step fashion. However, as is shown in Chapter 2 and further discussed in Chapter 4 of this SWOT – the research finds that the methods that are generally applied are often very straightforward and limited to certain areas of performance, and well documented in the performance measurement literature. For this reason, the focus on assessment methodologies largely documents which of the well-documented methods are applied in different corridor settings, the constraints or catalysts for the use of these methods – and the opportunities to introduce new or enhanced methods through the Playbook and its Appendixes. . A step-by-step description of methods will therefore be given in a subsequent report on recommended new methods that are not yet in the state of the practice, but which might enhance the effectiveness and interest in some of the specific corridor management examples included in the current SWOT. The SWOT seeks to address: **"What methods for quantifying impacts are currently utilized in corridor management and what are the constraints or catalysts for engaging a wider set of metrics and a wider view of impact?"**

Data sufficiency and availability

The SWOT considers the sufficiency and availability of data both for existing corridor impact regimes as well as for the decision support needs of groups that are managing corridors. Each assessment explicitly seeks out information on how corridor managers know if strategies are working, the types of analytics and resources that are available to corridor managers, and of those how many are actually used. The review of data sufficiency and availability also considers which measures are applied and how useful they are in the management process, as well as the reporting protocols and frequency with which corridor impacts are documented. The SWOT seeks to address **"what data and informational resources are readily available today within the context of existing corridor management practices, and how effectively are the data used in addressing impacts in corridor management?"**

Exhibit 8 **Critical Aspects of SWOT Case Evaluations**

Critical Aspects of SWOT Case Evaluations	90 94	95 85	15	45
Corridor definition and characteristics	◉	◉	◉	◉
Corridor management strategies	◉	◉	◉	◉
ACES (Autonomous, Connected, Electrical and Shared)	◉	◉	◉	◉
Methodologies to assess strategies	◉	◉	◉	◉
Data sufficiency and availability	◉	◉	◉	◉

In summary, the SWOT corridor evaluations consider the state of the practice within the context of the previously completed literature review and practice summary in a manner that accounts for five focus areas of corridor impact assessment, across four national corridor systems at nested levels of scale and complexity.

3.3 Nested Scanning Approach

Each corridor system is presented in the following chapter beginning with observations about how it is defined and managed at the national level. The view is understood to be much as the view of a planet through a telescope – allowing for a global understanding of the corridor, how it is understood at the national level within the context of national coalitions responsible for its management, and the role of impact assessment in that process. There is then an overview of active management coalitions serving the corridors at all levels.

Exhibit 9 **Nested Scanning Approach**

Each corridor SWOT then trades the "telescope" approach for a "magnifying glass" approach, making selected observations of sub-systems related to the corridor performance. These sub-systems consist of supportive multimodal systems that affect intended communities, supply chains, and other users. At this level more complex challenges – such as disparities in regional performance regimes, changing spatial and economic patterns of development, and differences in political jurisdictions shape the view of performance and impact and are reported in specific observations.

Finally, within each corridor system, there are observations of specific communities, neighborhoods, and businesses which relate to corridor performance. At this level, the SWOT observes as with a "microscope" things not visible at the national level, or even the inter-regional level but which can be decisive in terms of corridor management efforts having intended benefits. At this level, there is consideration of specific competing uses for space in a corridor's right of way, equity issues related to housing and disruptions in housing and land markets based on subtle changes in corridor alignments, and changes in the use of properties on ancillary transportation systems which may undermine a corridor's intended performance in the first or last mile or even ten miles.

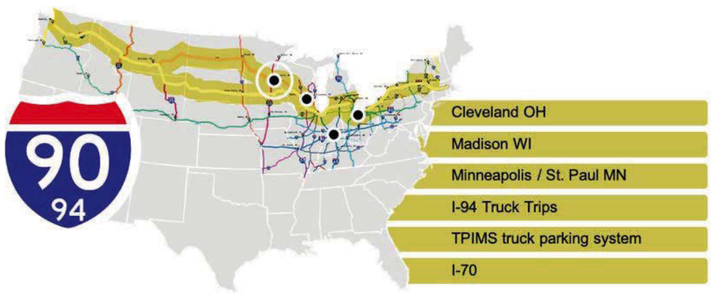
Why this Approach? The nested scanning approach not only provides a helpful framing of issues for the SWOT but has the potential to resolve fundamental issues which have impeded effective corridor management, as documented in Appendix 2. Most notably, there is often debate (or dismissal) regarding key topics in the management of corridors when corridor managers mistakenly perceive that the scope of corridor management should include **either** local/regional issues, **or** inter-regional issues, **or** state/national issues. **For example, corridor managers may dismiss growth management or community development as outside the purview of corridor managers as they are beyond the authority of state transportation departments. Local efforts may dismiss or even lament the state DOT's focus on throughput and high-speeds as antithetical to recognizing the value of corridors as local or regional development assets.**

With the nested scanning approach modeled in this SWOT, a construct of the Playbook and supporting framework is offered whereby any given corridor management effort may find its role within the larger corridor ecosystem, recognizing that while some performance areas are outside the scope of a particular coalition or study, there is an intrinsic relationship between each level. (Just as studying windstorms on Mars is beyond the purview of an orbiter, but appropriate for a lander and essential to understanding the planet). Hence, while a national group like the Eastern Seaboard Corridor Coalition would not plausibly address land-use indicators in Boston or growth management in Atlanta as a routine part of its corridor management – such a coalition can still recognize that these issues may, in fact, be decisive in achieving outcomes. The need to initiate or engage localized coalitions for certain aspects of performance can then become integral to a holistic impact management approach. In this way, the Playbook and supporting framework may be able to address the roles of national, regional, and local coalitions in relation to each other as has not been adequately understood to date. By framing the SWOT in this way, a key intention is to set a foundation for the Next Generation Corridor Framework to focus more on where each type of impact or management tactic fits in corridor management – stepping away from earlier dogmas which may have sought unduly narrow views of corridor performance limited by a particular jurisdiction, authorities or legislative mandates.

Impact Measures for Corridor Systems and Components

3.4. I-90/94 Corridor System

3.4.1 Overview



The I-90/94 corridor system has more active coalitions managing it than any other system in the current SWOT Analysis. It includes vast rural "bridge" sections that pass almost entirely through some US States generating little state revenue and also interfaces with major cities throughout the nation – affecting life in cities and towns hundreds of miles from its interstate facilities. The highway portion of the corridor interfaces with some of the nation's largest intermodal and multimodal freight facilities interfacing with rail, water, and airborne networks and international gateways. Stretching from Boston to Seattle Interstate 90 is the longest transcontinental freeway in the U.S. Travelling east to west, I-90 cuts across New England from Boston to Buffalo, NY, where it follows the southern shore of Lake Erie where it joins I-80 near Toledo, OH. Through the northern reaches of Ohio and Indiana, I-90/I-80 skirts the southern edge of Lake Michigan. After Gary, IN I-80 continues southwest, while I-90 follows the shore of Lake Michigan into the heart of Chicago where it merges with I-94. On the north side of Chicago, I-90 and I-94 split, with I-94 going north to Milwaukee, and I-90 going northwest to Rockford, IL before heading due north. I-90 and I-94 rejoin in Madison WI, only to separate again in Tomah WI. From Tomah, I-90 heads west across southern Minnesota, South Dakota, and the northeast corner of Wyoming. From Tomah, I-94 heads northwest through St. Paul, Minneapolis, Fargo, and Bismarck. In south-central Montana I-90 and I-94 join again to continue as I-90 across the remainder of Montana, Idaho, and Washington, linking to the ports of the Pacific Northwest.

East of Chicago, most of the I-90 Corridor is operated as tolled facilities like the Massachusetts Turnpike, New York Thruway, Ohio Turnpike, Indiana Toll Road, and Jane Addams Memorial Tollway (Illinois). The research conducted for the I-90/94 case study found few instances of active corridor coalitions east of Chicago.

Key Connections

As a transcontinental east/west artery, the I-90/94 Corridor intersects with most of the major north/south interstates, including I-5, I-15, I-35, I-55, I-65, I-71, I-80, and I-95. It connects to major rail terminals in Chicago as well as marine ports in Boston, Buffalo, Cleveland, Toledo, Chicago, Milwaukee, and Seattle/Tacoma. International border crossings occur with Canada in Niagara Falls, Port Huron, and Detroit.

The I-90/I-94 Corridor passes through numerous metropolitan areas. The largest urban areas on the corridor are listed below.

Exhibit 10 **Largest Urban Areas on I-90/94 Corridor**

Boston, MA	Detroit, MI	Minneapolis-St. Paul, MN
Worcester, MA	Ann Arbor, MI	Rochester, MN
Albany, NY	Elkhart-Goshen, IN	Fargo, ND
Syracuse, NY	Gary, IN	Sioux Falls, SD
Buffalo, NY	Chicago, IL	Billings, MT
Erie, PA	Rockford, IL	Coeur d'Alene, ID
Cleveland, OH	Milwaukee, WI	Spokane, WA
Toledo, OH	Madison, WI	Seattle, WA

3.4.2 Active Coalitions Partners and Inter-Regional Approaches to Assessing Corridor Impacts

The I-90/94 Corridor is home to six major multi-agency coalitions with varying areas of focus including general freight issues, ITS collaboration, multimodal transportation, and commercial needs. These coalitions are in addition to the individual state departments of transportation and metropolitan planning organizations adjacent to the corridor as it travels from the east to the west coast. A number of these coalitions are highlighted in the table of **Exhibit 11**.

Exhibit 11 **Coalitions and Groups Associated with the I-90/I-94 Corridor**

Focus Area	Active Coalition/Partner	Role of Coalition/Agency
IL, WI, MN, ND, MT, ID, OR, WA	Great Northern Corridor	Coalition for BNSF rail line, its commercial users, multimodal connection points, and state DOT's from Chicago to Washington.
MN, ND, SD, WY, MT, ID, WA	North/West Passage	Coalition for state DOT's from Minnesota to Washington to focus on ITS deployment.
PA, OH, MI	Smart Belt Coalition	The coalition is a regional, multi-jurisdictional, connected, and automated vehicle collaborative.
Maple Grove to St. Cloud, MN	I-94 West Corridor Coalition	The coalition includes businesses, individuals, and government agencies working to improve a 40-mile segment corridor and local area connections to businesses.
OH MI, IN, IL, IA, WI, MN	Gary-Chicago-Milwaukee Corridor Coalition Legacy	Coalition began as an interagency data sharing effort under SAFETEA-LU is now known as the Lake Michigan Interstate Gateway Alliance focusing on traffic operations.

Because the I-90/94 system has such a large number of coalitions, the SWOT for this system (unlike the other systems described in this chapter) addresses each of the five focus areas of SWOT for each coalition (as described below); in addition to a high-level focus-area summary at the end.

3.4.3 Coalition #1: Great Northern Corridor

Corridor Definition and Characteristics

The Great Northern Corridor (GNC) is an east-west multimodal transportation corridor stretching from Chicago to Seattle. Initially constructed by James J. Hill in the late 1800s, the Great Northern Corridor (GNC) was the only privately financed transcontinental rail corridor in the U.S. For decades the GNC rail line has served as a trade conduit for the manufacturers, ranchers, farmers, miners, loggers, sawmills, and energy companies that rely on transportation afforded by the corridor to access regional, national, and international (i.e., Asian-Pacific) markets.

Today the GNC is a multimodal artery stretching from Chicago to Seattle. The GNC provides mobility and economic vitality to more than 28 million Americans in eight states. The formation of the GNC Coalition started unknowingly in 2008, with the search for lower-cost transportation options to support a wind farm project in Shelby Montana. The wind project relied on the shipment of large components to North Central Montana from the Pacific Coast. But the turbines and fan blades that might otherwise move by rail were constrained by century-old "snowsheds" on the GNC rail line now owned and operated by BNSF. Snowsheds protect tracks and passing trains in avalanche-prone areas of the Rocky Mountains. The Mayor of Shelby, MT appealed to BNSF to modernize GNC assets so the line could accommodate wind project shipments. To identify other common needs among the many commercial users on the GNC, BNSF began contacting public agencies on the GNC about forming a coalition.

Corridor Management Strategies

Initially, a small coalition of just three states, several ports, and the BNSF formed around the idea of identifying needed rail improvements on the GNC. To entice broader coalition participation and access funds available through FHWA, the corridor was promoted as not just a rail corridor, but a multimodal system that relies on highways and ports to provide full-service freight transportation.[69]

Coincidentally, in late 2011, a Federal Register notice was also issued about a new grant program: Multistate Corridor Operations and Management (MCOM) Program. The notice invited "*existing and potential multistate organizations, coalitions, or other arrangements or entities engaged in transportation activities and research to apply…to promote regional cooperation, planning, and shared project implementation….*"[70] The GNC coalition applied and was awarded an MCOM Grant in August of 2012, with a goal: "*to promote regional cooperation, planning, and shared project implementation for research programs and projects to improve multimodal transportation system management and operations*."

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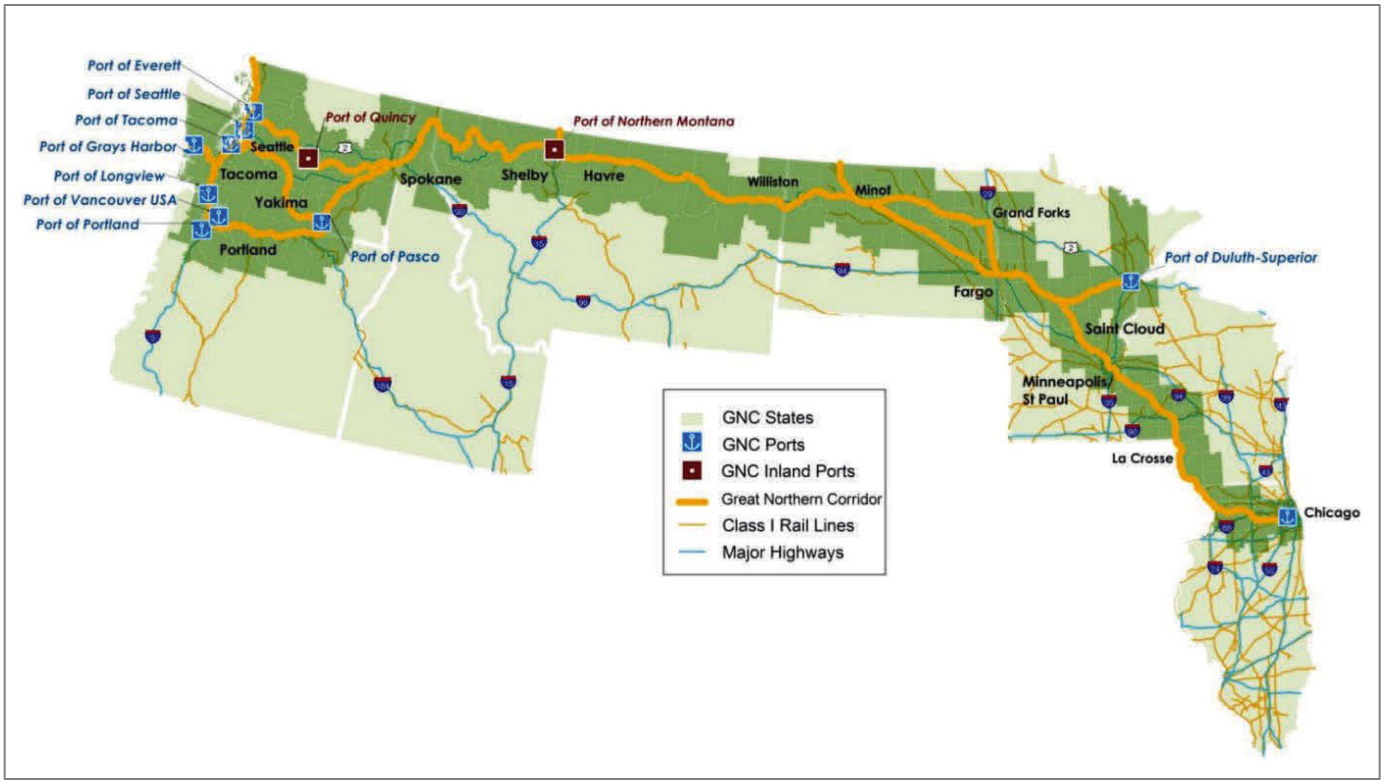
[69] Some states were reluctant to participate in a "rail corridor" coalition due to common legislative restrictions placed on gas-tax funded state transportation programs. Many states restrict the use of highway user fees on non-highway activities.

[70] Environmental Protection Agency, National Pollutant Discharge Elimination System (NPDES) Concentrated Animal Feeding Operation (CAFO) Reporting Rule 76 (October 21, 2011): p. 65561, https://www.govinfo.gov/content/pkg/FR-2011-10-21/pdf/2011-27189.pdf, 65561.

With the grant award, membership in the GNC coalition grew to include state DOTs from Illinois, Wisconsin, Minnesota, North Dakota, Montana, Idaho, Oregon, and Washington, as well as the Washington Public Ports Association, individual marine ports of Chicago, Duluth-Superior, Portland, Everett, Seattle, Tacoma, Grays Harbor, Longview, Vancouver, Pasco, and the inland ports of Northern Montana and Quincy, WA. A map displaying the state and port coalition members is shown in **Exhibit 12**.

Exhibit 12 Map of the Great Northern Corridor



Source: Great Northern Corridor Coalition – map created by Olsson Associates

Methodologies to Assess Strategies

One of the first activities undertaken by the Coalition was a SWOT analysis to define the Great Northern Corridor in economic terms as a multimodal conduit for commerce and trade. The work plan created an inventory of the rail, highway, and port assets in the corridor. The analysis also examined the industrial make-up of the corridor, highlighting key economic sectors in the corridor like agriculture, timber production, and manufacturing. BNSF provided a commodity flow dataset to the study effort to explore goods movement in the corridor.[71] The analysis concluded that most goods moving across the corridor traveled by more than one mode of transport and was also an important facilitator of trade with Canada and China. The impact of GNC was quantified in terms of the modal efficiently moving goods by rail versus truck. Hence reduced truck tons and truck miles were estimated and then transformed into the catalog of benefits shown to the right.

Exhibit 13 Impacts Quantified in GNC SWOT

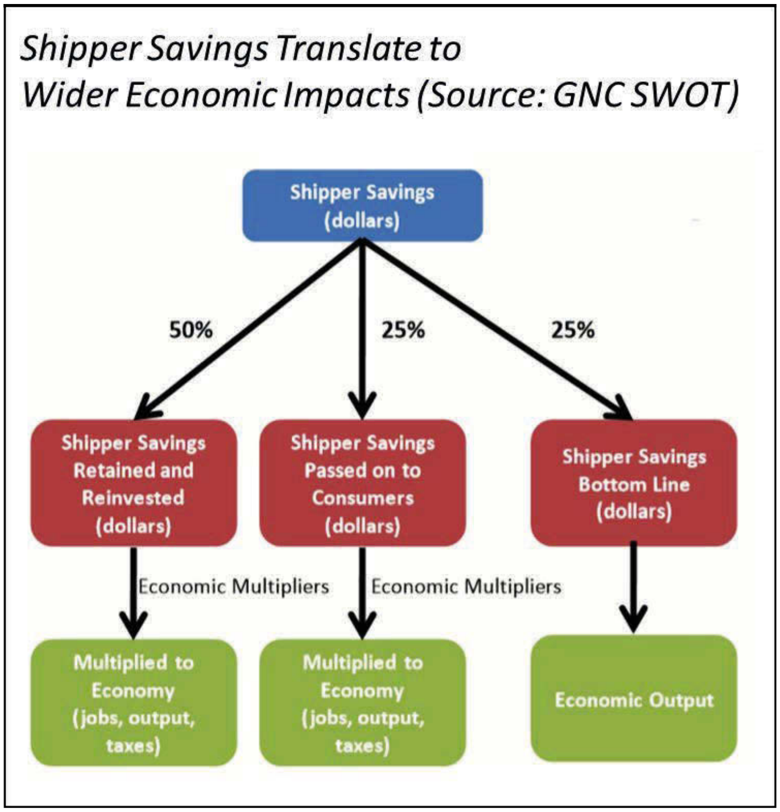
Impacts Quantified in GNC SWOT: Phase I (Source: GNC SWOT)

- State of Good Repair
  - Avoided Pavement Damage - Urban
  - Avoided Pavement Damage - Rural
- Economic Competitiveness
  - Customer Cost Savings
- Livability
  - Avoided Highway Delay
- Sustainability
  - Reduced Fuel Consumption
  - Avoided NOx
  - Avoided Particulate Matter (PM)
  - Avoided Volatile Organic Compounds (VOC)
  - Avoided CO_2
- Safety
  - Avoided Fatalities
  - Avoided Injuries
  - Avoided Damages

[71] The dataset provided by BNSF was TRANSEARCH from IHS-Markit.

The SWOT analysis also found that the eight coalition states relied on the corridor to exchange over 377 million tons of goods among themselves in 2014. The value tag applied to this inter-regional trade was $385 billion. Wider impacts were also quantified by converting the dollars of savings from avoided truck traffic into earnings, output, and employment using the IMPLAN-Based input-output framework of the PRISM model.

Exhibit 14 Shipper Savings



While much of the Phase 1 SWOT analysis was data-driven, a key element of the future corridor assessment relied upon stakeholder outreach, including an online survey of trends and a *Future Freight Flows Scenario Planning Workshop.* The scenario planning workshop held in Vancouver, WA drew approximately 50 participants from industry and government. Using a process developed through *NCHRP Project 750 Foresight Series*, attendees were assigned to one of four plausible futures and asked to discuss the implications for supply chains and transportation in each future.

Based on the data analysis and stakeholder outreach in Phase 1, the SWOT analysis arrived at several high-level conclusions:

- Environmental policy and environmental impacts will significantly affect and impact freight policy and project development in the future.
- Funding levels for infrastructure improvements have fallen behind, and existing funding mechanisms are inadequate to make the investments needed in the future. New funding approaches will be required, and the private sector is likely to play a larger role in infrastructure funding.
- The GNC benefits from the multimodal freight assets in the corridor. The mix of modal assets allows the corridor to respond to changing commodity movements and allows for more efficient and environmentally sound transportation options.
- The formation of the GNC coalition was viewed as a good first step to capitalize on economic development and infrastructure investment opportunities.

In 2014 the GNC Coalition applied for and received a second MCOM grant to continue building coalition efforts and develop resources to support future corridor management activities. Major activities in Phase 2 included:

- An analysis of truck trips generated by the 20 largest water ports and rail facilities on the GNC.

- An analysis of cross-border trade flows to/from the GNC and Canadian Provinces.
- An at-grade crossing safety and mobility initiative.
- Corridor-wide preliminary environmental planning initiative.
- A unified corridor investment plan.

In Phase 2 the coalition began to galvanize around three key activities: 1) Marketing the value of a multimodal GNC corridor; 2) Preparing resources to position the GNC to compete well for federal infrastructure grant programs, and; 3) Developing a business plan for the coalition to continue without MCOM grant funding.

1. Marketing the value of the GNC Corridor: During the MCOM grant study, the GNC coalition created a website, largely for marketing the economic value of the corridor in connecting businesses with national and international markets. The website can be found at https://greatnortherncorridor.org/

2. Preparing resources to position the GNC to compete well for federal grants: The era of Congressional earmarks had effectively come to an end in 2011, replaced by transportation grant programs. Members of the coalition believed they could be more successful overall if all members of the coalition would support the corridor's top-ranked projects. Using project ranking criteria developed during the course of the SWOT study, coalition members sponsored 14 infrastructure projects across the corridor for a variety of grade-crossing, rail, and port projects. In Fiscal Year (FY) 2014, the fourteen projects identified were submitted as grant applications to test the evaluation criteria. One applicant (the Port of Seattle) was successfully awarded a $20 Million TIGER capital grant for its Terminal 46 Modernization project. In FY 2015, two additional GNC projects were awarded grants: The Willmar Connection and Industrial Spur in Minnesota, and the Kalispell Rail Park in Montana.

3. Developing a business plan for GNC Coalition subsistence: The final meeting convened by GNC Coalition under the MCOM grant project devoted significant time to discussing how the coalition would be structured to continue in the absence of federal grant funding. The coalition created an Executive Leadership and Working Committee Structure, as well as a membership fee structure. Recent discussions with coalition members indicate that until the COVID-19 pandemic, the working group was holding conference calls twice per month and the executive leadership team was meeting by teleconference once per quarter. The Executive Director, a former port official, is acting in a volunteer capacity for the coalition.

Before concluding the MCOM funded study, the coalition had quantified the impacts of the corridor's performance to date on each of its member states using the metrics described in the Exhibits above. The primary metric was the economic impact of the corridor on the individual state economies of the coalition, as well as for the coalition region. To estimate the economic impact of the GNC in each state, employment in freight transportation dependent industries in the counties that defined the Corridor were measured against the employment of comparable industries in each state. The economic impact of freight transport in the corridor was assumed to be proportional to the share of the employment of the GNC counties in each state. The methodology estimated that the corridor had an economic impact of $500 billion on the combined economic region. The impact of the corridor on individual states' Gross State Product (GSP) ranged from 3.9% (Wisconsin) to 41.2% (North Dakota). Metrics were also used to estimate the benefit of the strong rail presence in the corridor. These impact metrics coincide with benefits examined in the benefit-cost analysis (BCA) for federal infrastructure grant programs like BUILD and INFRA.

During the study effort, methodologies were developed, and values were produced for each of the listed metrics on a corridor-wide basis. While the methodologies for deriving these metrics were carried over into

BCA templates developed to evaluate projects, no ongoing monitoring or updates to these metrics across the GNC has occurred. During interviews, it was noted that without external funding for data analysis, corridor-wide monitoring is not possible.

Autonomous, Connected, Electric, and Shared Technologies

The initial GNC Phase 2 study work considered an examination of ITS strategies for the corridor, but due to the work of the North/West Passage Coalition, the group declined to conduct further study on technology development in the corridor.

Data Sufficiency

The data sources used in conducting the analyses in the GNC SWOT Analysis came from a variety of public and private data sources. BNSF Railway contributed TRANSEARCH a proprietary commodity flow database, as an in-kind contribution worth $30,000 -$40,000. The study also purchased data services from the American Transportation Research Institute (ATRI) to examine the interaction between port and rail facilities and major highways in the corridor. However, no ongoing data program to update analyses or performance metrics was established.

One of the deficiencies recognized by coalition members in the federal grant process was the lack of readily available environmental data related to projects in the corridor. To address this issue, the coalition did develop an environmental land-use database to identify tribal lands, protected areas, and other environmentally sensitive properties in the corridor.

Post MCOM Operations

Since the MCOM funded study efforts of the coalition ended in 2016, the GNC Coalition has continued to meet under the direction of a volunteer executive director. A fee schedule for member participation has been established and the coalition continues to work cooperatively to apply for federal grant opportunities to fund projects on the corridor.

3.4.4 Coalition #2: The North/West Passage

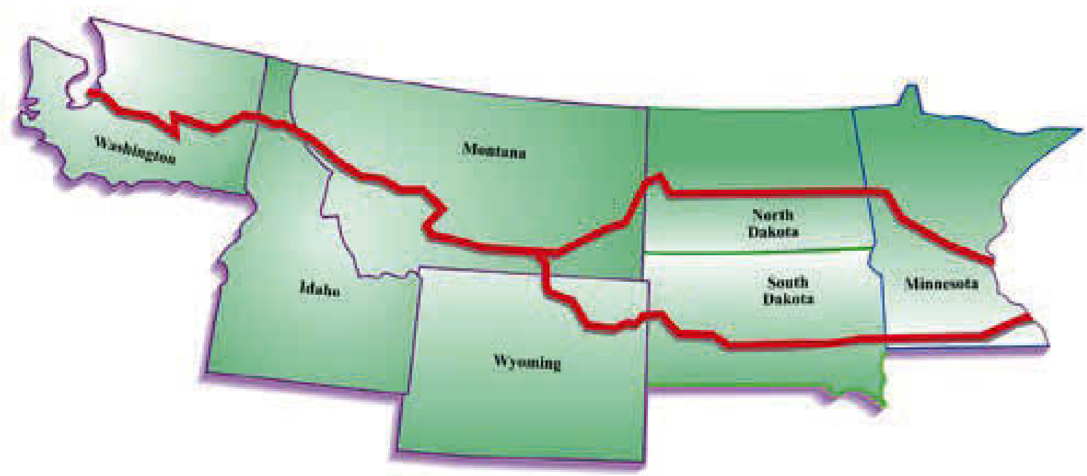
Corridor Definition and Characteristics

The North/West Passage (NWP) Transportation Pooled Fund Study is focused on Interstates 90 and 94 as they travel from Minnesota to Washington. It is comprised of seven state DOT's including Minnesota, North Dakota, South Dakota, Wyoming, Montana, Idaho, and Washington. The vision of the Corridor is to focus on developing effective methods for sharing, coordinating, and integrating traveler information and operational activities across state and provincial borders. The vision provides a framework to guide the states' future projects in the corridor.[72] The NWP group was originally formed to coordinate cross-border collaboration in the deployment of Intelligent Transportation Systems (ITS)

[72] "2021 Brochure," 2021 Brochure, accessed October 26, 2021, https://www.nwpassage.info/downloads/nwp_brochure.pdf.

to address issues related to winter weather conditions, traffic management, traveler information, and commercial vehicle operations.

Exhibit 15 Map of the North/West Passage Corridor Coalition



Source: North/West Passage Corridor website: https://www.nwpassage.info/

Corridor Management Strategies

Beginning with a meeting in 2002, the eight states of the coalition formally coalesced as a Transportation Pooled Fund established in 2003. Since then, the NWP pooled fund group has undertaken a multi-phased program to integrate ITS systems and traveler information across the corridor. The NWP Coalition has developed an ITS Integrated Strategic Plan and successfully implemented twelve work plans. The group is currently working on its thirteenth work plan consisting of four projects presented in **Exhibit 16**:

Exhibit 16 NWP Pooled Fund Work Plan 13 (April 2019)

NWP Project	Results and Outcomes
1. Operations Task Force –Year 6 (2019)	Held periodic webinars on operations related topics (e.g., Pathfinder and Wyoming DOT Connected Vehicle Pilot Project Update).
2. Freight Task Force –Year 4 (2020)	The intent of the freight task force is to enhance NWP activities with the freight community and efforts.
3. NWP Corridor and Safety Mobility (2020)	This project will conduct an overall assessment of the safety and mobility issues and challenges along the I-90 and I-94 NWP corridor.
4. North/West Passage Traveler Information Work Zone Alerts: Feasibility Study (2019)	The purpose of this project is to understand what changes might be needed to each NWP state's traveler information system and work zone reporting procedure to provide work zone alerts to travelers.

Source: NWP Website: https://www.nwpassage.info/

The NWP Group's initial strategic plan developed in 2007 sought to address the common areas of input from state members on problems and needs related to the corridor. That initial effort identified three common areas of concern:

1. Traveler Information
2. Maintenance and Operations
3. Planning and Program Management

Over time these initial themes have expanded to include three additional focus areas that in recent years have guided the work plans developed by the group:

4. Staffing and Resources
5. Connected and Automated Vehicles
6. Freight

In addition to developing areas of common concern, the 2007 strategic plan also developed a vision for the group:

> *The vision of the North/West Passage Corridor is to focus on developing effective methods for sharing, coordinating, and integrating traveler information and operational activities across state and provincial borders.*

Using the vision as the common guidepost, the group meets annually to develop work plans around the six focus areas.

Methodologies to Assess Strategies

In an interview with Dave Huft, Research Program Manager for South Dakota DOT, and current steering committee chair for the NWP corridor coalition, he indicated that it is important to understand the very rural nature of the NWP corridor: "*While many corridors focus on mobility and recurring congestion, our focus has been on environmental conditions and communicating travel conditions to corridor users.*"

The coalition has focused on developing common standards and reporting formats to share data and information across the corridor, as well as package and provide information to corridor users. Emphasizing the focus on communicating environmental conditions, i.e., major weather events, one of the first projects was extending 511-traveler information in Minnesota, to travelers in North Dakota and South Dakota. From those initial steps, the group has developed a one-stop website for traveler and trucker information sites in each state in the corridor. Mr. Huft noted that one of the corridor's recent projects has established an online dashboard for each coalition state to display metrics related to safety and mobility. However, at this point, the coalition has not viewed the dashboard as an ongoing data collection platform to monitor progress. He said the coalition has attempted to conduct more formal program evaluations in the past, but external factors have made it difficult. As one example, several years ago, three states in the corridor raised the speed limits in the corridor posing the question, "*how do you distinguish the impact of NWP program activities on safety from external changes like higher speed?*"

One of the greatest benefits of the pooled fund effort has been the peer-to-peer learning and sharing of information across the corridor. An outcome that is difficult to measure in numeric terms. The NWP group signed a memorandum of understanding (MOU) to facilitate the coordination of traveler information in the corridor. The group received the ITS America Award for Best Rural ITS project in 2010. Numeric

Autonomous, Connected, Electric, and Shared Technologies

As already discussed, NWP was founded and continues to exist to share information about and through advanced traveler information technologies. In 2015, the Wyoming Department of Transportation (WYDOT), an NWP member was awarded one of three grants nationwide under the Connected Vehicle (CV) Deployment Pilot Program. The Wyoming CV Pilot is the only award to focus on commercial vehicle operations. The goal of the project is to test connected vehicle technologies that could improve the safe travel of trucks during inclement weather – a common issue in the open plains environment. Even though the WYDOT CV Pilot is taking place on I-80, the most recent NWP work plan includes a project to incorporate results from the I-80 pilot in the NWP states:

> *The architecture of the Wyoming CV Pilot deployment included development of a situational data warehouse. The sources of data to this data warehouse include data collected by connected vehicles, weather data from the Pikalert system, incident information, work zone data, and parking information.*
>
> *This situational data warehouse could support other NWP states, allowing them to post their data to this system and to access Wyoming's data, effectively expanding to a connected vehicle data source for the NWP corridor. The data warehouse can support a lot of functions, including fleet operators downloading data and infrastructure to vehicle communications.*
>
> *This project will allow NWP members to understand the potential of using and expanding this warehouse, while also understanding the ongoing cost implications (both for operations of the warehouse and connections to the warehouse).*

Data Sufficiency

Communications with several coalition representatives indicated that states do provide benefit summaries in applying for or justifying the $25,000 each member contributes to the pooled fund annually. These benefit summaries are typically more qualitative than quantitative in nature.

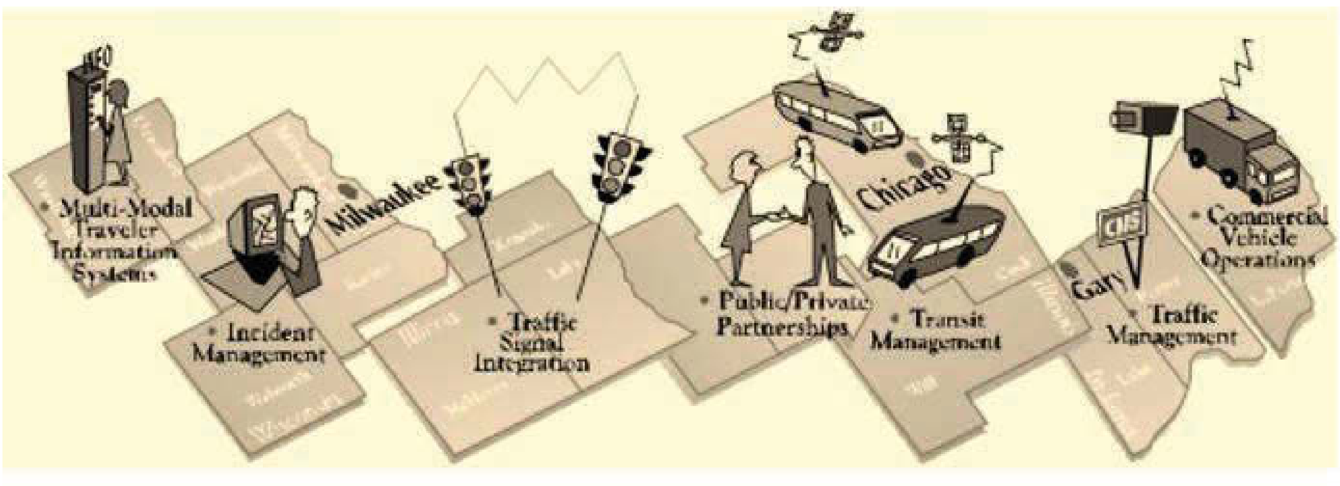
During the conversation with Mr. Huft, he noted that at a recent annual meeting, the coalition agreed to fund a Situational Data Warehouse modeled after a data repository created for the WYDOT CV Pilot. While the intended purpose is to better prepare the corridor for future connected vehicle activities, Mr. Huft suggested it might also provide a portal to begin collecting more performance-related data in the corridor. He also noted that the recently completed dashboard tool that is based on federal performance metrics for mobility and safety could be used to establish time-series metrics and allow for ongoing performance monitoring. He also noted that due to the coalition's focus on environmental conditions in the corridor; they have held discussions around a "winter level-of-service" metric that would incorporate winter road conditions.

3.4.5 Coalition #3: The Gary-Chicago-Milwaukee (GCM) Corridor Coalition's Legacy

Corridor Definition and Characteristics

The GCM Corridor Coalition was established in 1991 and was one of the three initial corridor coalitions supported by SAFETEA-LU as an ITS Priority Corridor. The cooperative effort included states, counties, and metropolitan areas in order to bring existing/legacy and planned systems and services into an integrated framework of Corridor ITS Services. Traveling through the highly industrialized Greater Chicago Region, the coalition was driven by the belief that traffic congestion prompts agency collaboration. It was also one of the first ITS corridor deployments with a specific emphasis on commercial vehicle operations.

Exhibit 17 A Case Study: Gary-Chicago-Milwaukee ITS Priority Corridor



Courtesy of BRW, Inc.

SOURCE: USDOT, FHWA: Regional ITS Architecture Development – A Case Study: Gary-Chicago-Milwaukee ITS Priority Corridor, 1999

The GCM served as a precursor to what is now known as the Lake Michigan Interstate Gateway Alliance with the goal to focus on traffic operations to ensure safe and efficient movement. It relies upon interagency communication and coordination, improvement projects, training efforts, and regionwide planning. Members include the Wisconsin Department of Transportation, the Illinois Department of Transportation, the Indiana Department of Transportation, the Michigan Department of Transportation, the Illinois Tollway, the Skyway Concession Company LLC, and the Indiana Toll Road Concession Company LLC.

Other multi-jurisdictional ITS-based efforts associated with the I-90/94 Corridor in the region included the Great Lakes Region Traffic Operations Coalition (GLRTOC) and ITS Midwest. ITS Midwest was the first multistate chapter of ITS America and was formed by the three-state consortium responsible for the Gary-Chicago-Milwaukee Corridor. Its current members include the City of Chicago, FHWA, IDOT, Illinois Tollway, Indiana Toll Road, Lake County Division of Transportation, ODOT, and 40 plus private companies.

Corridor Management Strategies

ITS Midwest provides real-time traffic information via online maps for a number of metro regions. The online maps contain information regarding congestion, construction, weather, incidents, special events, among others. ITS Midwest also provides a number of reports related to the collected data including travel time, congestion, incidents, construction, camera, message signs, special events, weather stations, and reports geared specifically for truck drivers. ITS Midwest covers the following metro regions: Chicago, IL; Rockford, IL; Gary, IN; Detroit, MI; Minneapolis-St. Paul, MN; Madison, WI; Milwaukee, WI; and Toledo, OH.

The ITS Midwest system monitors received traffic data from all major traffic management systems associated with its members. These systems use a wide range of traffic detection technologies to monitor speed and concentration of vehicles. Based on the collected data, traffic congestion levels and travel times are computed. These systems also provide messages currently displayed on dynamic message signs located along the roadways. Information about incidents and construction-related road closures is received electronically from several site contributors. Additional information is entered manually by Travel Midwest operators from a series of reports, and the operators also check and correct the automated accident entries. This blend of automatic data and manual entry help to keep the information available to drivers as current and accurate as possible.

Exhibit 18 **ITS Midwest System Monitors**

Autonomous, Connected, Electric, and Shared Technologies

While autonomous, connected, electric, and shared vehicles did not exist during the time of the GCM, there was an awareness about the need for cooperation among private sector partners, most notably the original equipment manufacturers (OEM) and cellular companies, the USDOT, and the Federal Communications Commission (FCC) in order to fully enable the safety benefits of vehicle-to-infrastructure and vehicle-to-vehicle connectivity technologies. Automation will most likely be first seen in supply chains along multistate highway corridors servicing the trucking industry's ramp-to-ramp movements and associated needs of manufacturers and other companies providing the first and last mile of deliveries.

Methodologies to Assess Strategies

For a time period, performance dashboards related to work zones and weather impacts among others were maintained by GLRTOC via the Traffic Operations and Safety Laboratory (TOPS Lab) at the University of Wisconsin – Madison. In particular, the dashboards included a seasonal map highlighting planned work zones in the region based on member agency discussions related to upcoming projects, neighboring work zones, and opportunities for collaboration, as well as travel times through work zones. A second mapping application allows users to compare temporal changes in travel time performance on the NHS via a sliding bar tool. However, due to a loss of staffing resources and expertise at the TOPS Lab, this capability is no longer available.

Exhibit 19 **CLRTOC Corridor and Workzone Map**

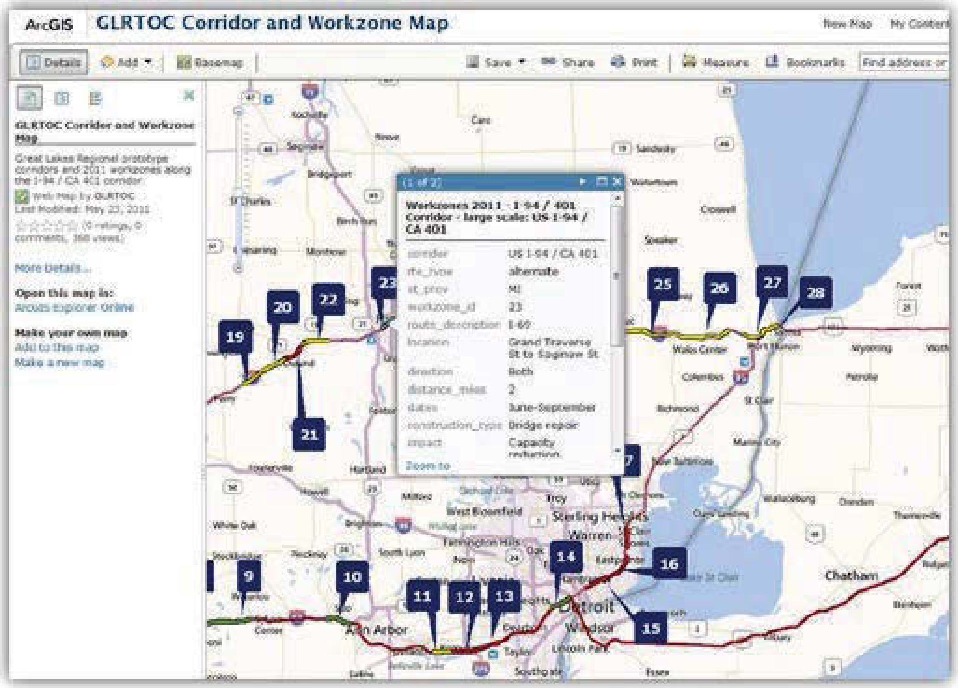


Exhibit 20 **Planning Tour Dashboard**

Exhibit 19 and **Exhibit 20** illustrate the Workzone map and the dashboard. There is no current methodology for weighing competing goals and strategies on routes providing redundancy to federal aid capacity. For example, how are competing interests on the U.S. or state highway parallel to a major interstate corridor weighed if urban planners at the local level are planning for and implementing a *Complete Streets* approach with sidewalks, bicycle facilities (such as protected bike lanes in urban areas), special bus lanes, comfortable and accessible public transportation stops, frequent and safe crossing opportunities, median islands, accessible pedestrian signals, and ramps, curb extensions, and narrower travel lanes while state planners are planning for a redundant network to move traffic to during a major incident on the interstate?

Data Sufficiency

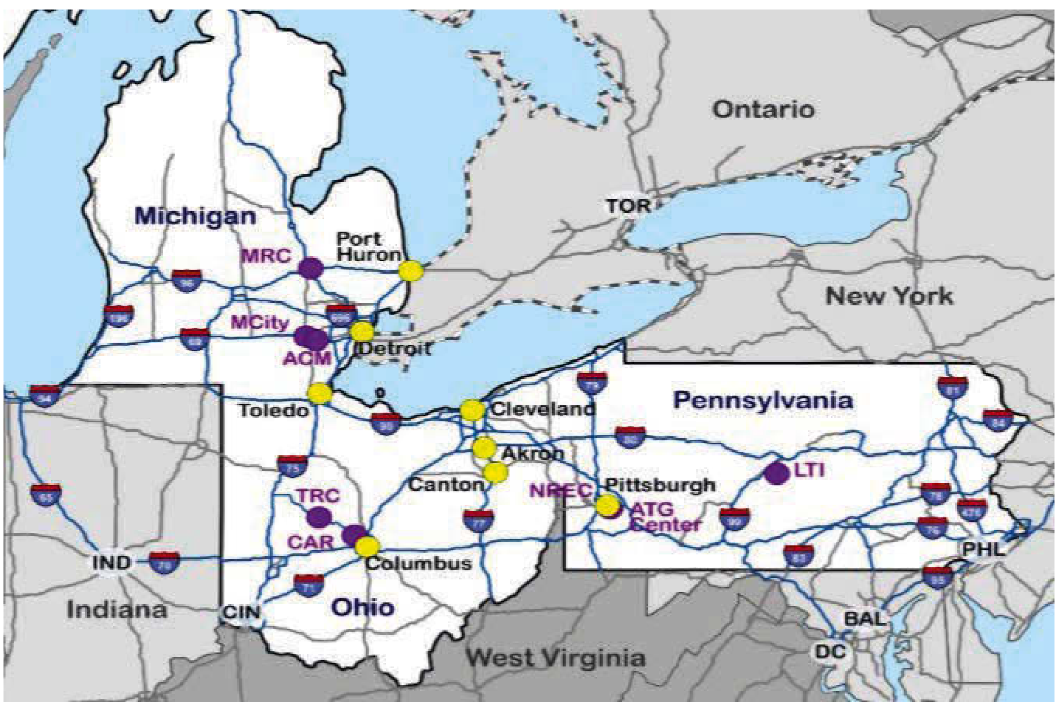
The ITS Midwest system monitors received traffic data from all major traffic management systems in the area including the Illinois, Indiana, Wisconsin, Michigan, Minnesota, Ohio, and Iowa Departments of Transportation, the Illinois Tollway, the Chicago Skyway, the Indiana Toll Road, and the City of Chicago and Lake County Illinois Divisions of Transportation. These systems use a wide range of traffic detection technologies to monitor speed and concentration of vehicles. Based on the collected data, traffic congestion levels and travel times are computed. These systems also provide messages currently displayed on dynamic message signs located along the roadways. Information about incidents and construction-related road closures is received electronically from several site contributors. Additional information is entered manually by Travel Midwest operators from a series of reports, and the operators also check and correct the automated accident entries. This blend of automatic data and manual entry help to keep the information available to drivers as current and accurate as possible.

3.4.6 Coalition #4: Smart Belt

Corridor Definition and Characteristics

The Smart Belt is a multijurisdictional/regional connected and automated vehicle (CAV) collaboration along a long-distance network of urban and rural roadways. Its mission is to bring together transportation agencies, academic and research institutions, and others in order to work on initiatives that further the utilization of connected and autonomous vehicles in its partners' states. The coalition includes the Michigan, Ohio, and Pennsylvania DOTs, the Ohio and Pennsylvania Turnpikes, FHWA, and several research institutions: Carnegie Mellon University, Penn State University, the Ohio State University, the Transportation Research Center Inc., the University of Michigan, Kettering University, and the American Center for Mobility. The pooled-fund study is scheduled to kick off in July of 2020.

Exhibit 21 Map of the Smart Belt CAV Coalition



SOURCE: Cole and Shuey, https://www.ibtta.org/sites/default/files/documents/2017/Atlanta/Cole_Shuey.pdf

Corridor Management Strategies

The Smart Belt Coalition is setting out to make roadways ready for connected and autonomous vehicles and to provide the needed support to the companies designing and building those vehicles. The effort is relying on collaboration to share responsibility, skill sets, and expertise, best practices related to legislation and regulation, as well as to pool financial resources, improve effort efficiency, increase funding opportunities, leverage federal grants, and build beneficial long-term relationships. A key management strategy will be focusing on promoting interoperability throughout the state and states from urban to rural environments so that there are no issues when traveling from one city to the next. Near-term projects include work zone reservation and traveler information systems, intelligent work zone detection, freight truck platooning and parking, and other connected vehicle applications.

Autonomous, Connected, Electric, and Shared Technologies

One of the main impacts members of the coalition see from connected and autonomous technologies will have on transportation is in supply chains and logistics. In particular, will be the need for locations to conduct the freight hand-offs between the long-haul movements along interstate corridors and the first/last mile moves along the local corridors. Unmanned Aircraft System (UAS) technologies will also play and a role in the first/last-mile deliveries and relieve roadway congestion, so again, identifying and providing locations for the hand-offs will be important. Also expected is as more and more CAV adoption occurs, corridors will experience a reduction in speed variability (e.g., vehicle speeds ranging from 65 to 80 mph) will produce more streamlined traffic and the anticipated efficiency and safety benefits.

Methodologies to Assess Strategies

While the coalition has yet to kick off its operations, the three state DOTs and two turnpikes currently have a number of corresponding services that will allow for shared assessments along the corridors. Some of these service layers relate to the near-term projects discussed above, including work zones traffic incident management, freight, safety, integrated corridor management, and weather (Exhibit 22). An innovative strategy to assess the impact of CAV's impact on ICM and safety will be to monitor the variability of vehicle speeds (e.g., ranging from 60 to 80 mph versus 65 to 72 mph) traveling within the corridors with the idea being traffic experiencing less variability will produce improvements for efficiency and safety. By 2022, the coalition expects to be a worldwide leader in the CAV space, be able to show proof of concept related to its collaborative model via implemented solutions, as well as provide examples of safety, economic development, and mobility improvements.

Exhibit 22 The Smart Belt Coalition's Operational Agency and Service Layer Matrix

	OPERATIONAL AGENCY				
SERVICE LAYER	MDOT	ODOT	OTIC	PennDOT	PTC
Work Zones	●	●	●	●	●
Traffic Incident Management		●	●	●	●
Freight	●	●	●	●	
Safety Applications (Curve Warning, Low Vertical Clearance)		●	●		●
Integrated Corridor Management (Traffic signals, ramp metering, transit priority)	●			●	
Weather	●				●
Traveler Information					
Customer Service Applications (Tolling Points, Service Plazas, Border Crossings)					

SOURCE: Cole and Shuey, https://www.ibtta.org/sites/default/files/documents/2017/Atlanta/Cole_Shuey.pdf

Data Sufficiency

As was noted above in the Corridor Management Strategies section, a key component of the coalition is the collaborative effort related to funding and best practices. Collaboration will extend to the sharing of data, especially as it relates to the services in Exhibit 22 above. One of the initial efforts will relate to truck platooning technology such as longitudinal and lateral control and vehicle-to-vehicle communications. The study will identify the data requirements to allow automated truck technology to travel along a corridor that passes through the three states while satisfying both administrative and procedural requirements. A second effort will focus on the data-sharing requirements to link scheduled work zones across multiple agencies, for example, to identify particular times when roadwork can be scheduled. The effort will also standardize work zone data to integrate with multiple traveler information and connected vehicle applications in a single defined format. The plan is to develop these systems using open source software and code to allow for future integration across multiple agencies into ITS, operational, and data systems and processes, as well as to allow for integration of future technologies. The coalition will also standardize procedures for applying to test CAVs within the three states, standardize the way CAV crashes are reported and tracked, and standardize the regulations for operating passenger and commercial vehicles. There is not currently a framework for who will supply which data elements, how they will be organized or utilized over time. In this regard, like many of the coalitions – Smart-Belt may be a significant beneficiary of the Playbook and its supporting framework.

3.4.7 Selected Observations: Metropolitan Areas

Corridor "Stop" #1: Cleveland, OH ITS-Based Variable Speed Limits During Winter Whiteouts

I-90 in Lake County, OH (east of Cleveland) was a hot spot for winter white-outs due to its close proximity to Lake Erie and lake effect snow events. This issue affects both the performance of I-90 as a facility – as well its ability to support the local economy of the County and its associated economy. The winter white-outs, which reduce drivers' visibility and cause stopped traffic, have produced numerous 50 plus vehicle pileups. The image in **Exhibit 23** shows a Lake County Sheriff's Office image of a 50- vehicle pileup from December 9th, 2016 which shut down I-90 for 14 hours. To improve safety and reduce closures and delays along the I-90 Corridor, the Ohio Department of Transportation (ODOT) eschewed a traditional approach relying on drivers slowing their vehicles to a safe speed for the conditions based on personal experience, winter weather messaging systems, and digital roadway signs, and implemented a Transportation Systems Management and Operations (TSMO) solution.

The solution: to utilize technology in the form of cameras and weather sensor stations to monitor road and weather conditions along a 12-mile stretch of I-90 and then communicate variable speed limits to drivers using dynamic message signs (DMS) spaced one to two miles apart. In order to implement the variable speed limits, ODOT needed approval from the state legislature. Besides I-90, the legislature granted ODOT the variable speed limit authority along I-670 in Columbus and I-275 in Cincinnati.

Exhibit 23 **Image from a 50-vehicle pileup along I-90 in December 2016**

SOURCE: https://www.usatoday.com/story/news/2016/12/09/heavy-snow-triggers-50-car-pileup-ohio/95196868/

The ITS program utilizes a number of performance measures to track its effectiveness.[73] These include:

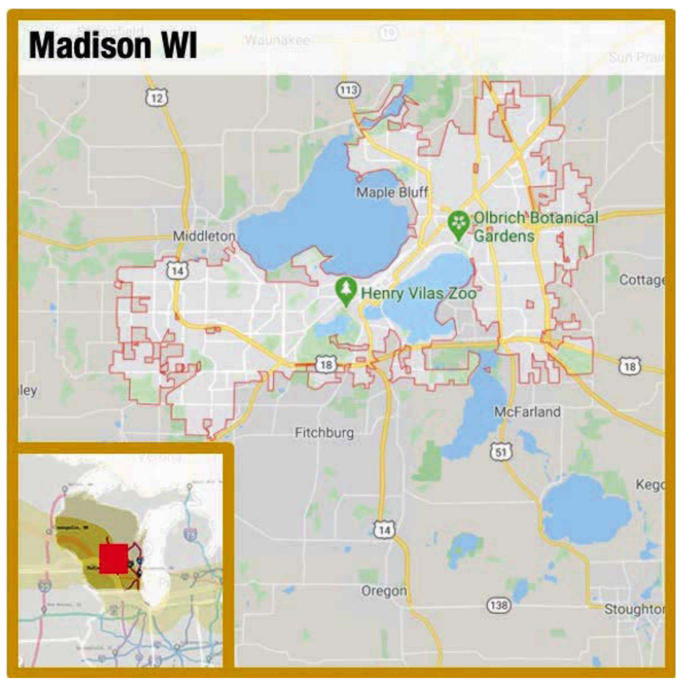
- Crashes when snowing
- Secondary crashes
- Total crashes
- Incident clearance times

A before (2014-2016) and after (2017-2019) comparison shows positive results despite a 15 percent increase in the number of days with snow. Total crashes decreased from 296 to 234 (-21 percent) while crashes during falling snow went from 138 to 83 (-40 percent). Secondary crashes have been reduced by 25 percent as well. Average incident clearance times were 112 minutes before and 81 after resulting in a reduction of user delay cost from $2,128, 804 to $364,281 and person-hours of delay from 87,949 to 14,777. Most importantly, there have been zero fatalities or major pileups in the corridor since the program's inception.

Program managers have identified a number of areas for further improvement. One, better real-time data related to traffic speeds and weather along the corridor. Two, improved algorithms for recommending when to lower speeds and thereby remove the speed limit determinations from the traffic management center (TMC) operators. Third, implement connected vehicle technology with the state highway patrol vehicles and ODOT maintenance vehicles to share the variable speed limit and weather conditions in real-time. The hope is to be able to duplicate and implement the TSMO solution with additional service capabilities and data to realize the safety and travel time benefits in other parts of the state's transportation network.

3.4.8 Corridor "Stop" #2: Madison, WI ITS Strategic Plan

Connected to the nation through the nexus of I-90 and I-94 Madison is both the capital of Wisconsin and the center of a dynamic region with a multimodal transportation system facilitating its connection to this vital national system. The Madison Metropolitan Area consists of all or portions of 27 cities, villages, and towns within Dane County including the City of Madison. It is the second fastest-growing Midwest city with a population of 200,000 or more.[74] Its population is expected to increase from roughly 233,000 in 2010 to 383,000 in 2050. Its economy is heavily influenced by the state government and the University of Wisconsin and its major industries of healthcare, biotechnology, health and information technology, agribusiness/food, insurance, financial services, and precision manufacturing. Approximately 40,000 workers travel into Dane County per day, while roughly 10,000 travel



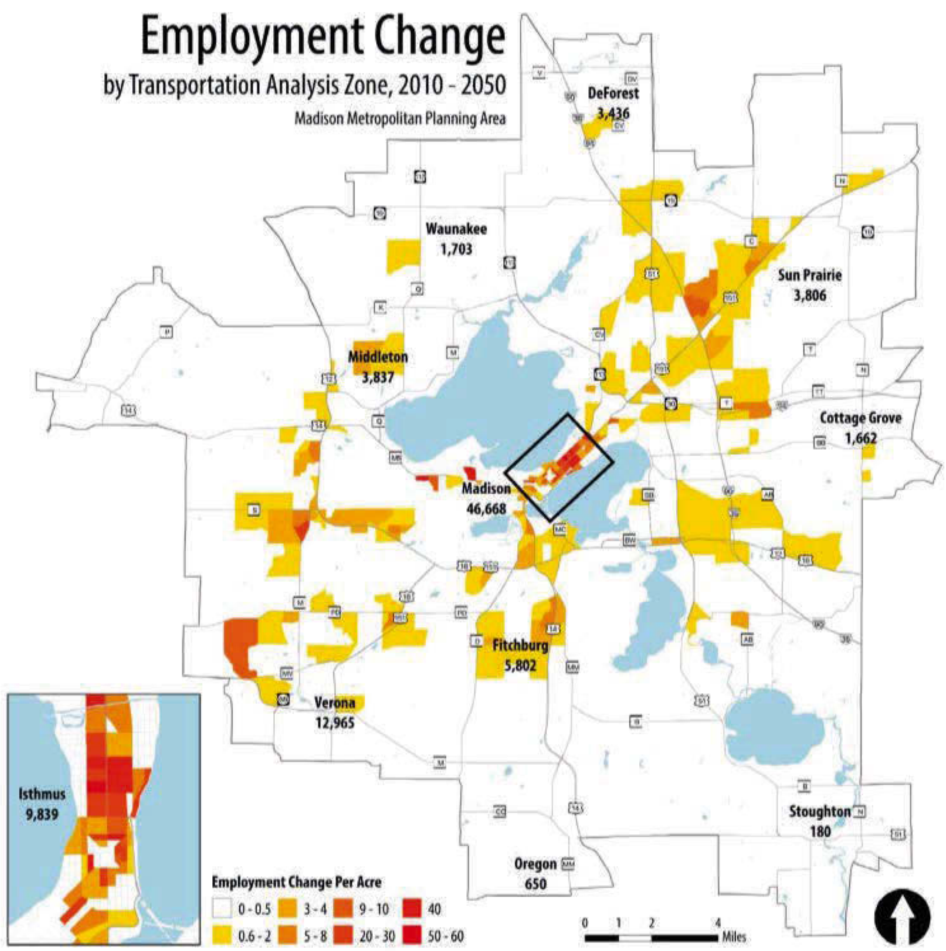
[73] Ohio DOT, "TSMO - Case Study: I-90 Lake County," Ohio DOT, accessed October 26, 2021, https://www.transportation.ohio.gov/wps/portal/gov/odot/programs/tsmo/case-studies/tsmo-case-study-i-90.

[74] Madison Area Transportation Planning Board, "RTP 2050 MMA," Regional transportation plan 2050, April 5, 2017, https://www.greatermadisonmpo.org/planning/RegionalTransportationPlan2050.cfm.

from Dane County to surrounding counties. Projections estimate 99,000 workers will commute to Dane County by 2050.

Its unique geography, with its downtown and campus area situated on an isthmus with lakes and natural resources, creates significant barriers to traffic circulation. While the lack of direct connectivity between its downtown and the I-90/94 Corridor has contributed to downtown Madison's livability, it has created significant traffic growth on its arterial streets which radiate from the Capitol Square before connecting to state highways and the I-90/94 Corridor, as well as the Beltline which provides the only east-west connection between I-90/94 and the west-side of Madison. 2050 Employment forecasts predict continued growth in the isthmus (Exhibit 24), producing daily commutes of 99,000 by 2050 into Dane County from other counties (40,000 in 2010). Consequently, congestion along the I-90/94 Corridor adjacent to Madison is not an issue during weekly AM and PM commute hours but occurs due to seasonal recreational traffic traveling north on Friday PM hours and south on Sunday PM hours. WisDOT is in the process of incorporating dynamic part-time shoulder use and other enhanced ITS tools to improve capacity along the Beltline during AM and PM peak traffic.

Exhibit 24 Employment Change by Transportation Analysis Zone



SOURCE: Madison Area Transportation Planning Board, "Regional Transportation Plan 2050: Charting Our Course."

MMA's ITS Strategic Plan was created to develop a prioritized plan for implementing ITS strategies so that the required data would be collected and shared to fully implement the region's Congestion Management Process (CMP) and facilitate more performance-based multimodal transportation planning. The plan serves as a supplement to a number of WisDOT ITS Initiatives, including the Traffic Operations Infrastructure Plan (TOIP), the Arterial Infrastructure Management (AIM) Plan, and the Transportation Systems Management & Operations (TSMO) – Traffic Infrastructure Process. It conforms to the National ITS Architecture standards including a number of service areas:

- Archived Data Management
- Public Transportation
- Emergency Management
- Traveler Information
- Traffic Management
- Maintenance & Construction Management
- Vehicle Safety

Prior to the plan, there had been little coordination within the region to develop a process by which to identify ITS strategies and projects that would reduce congestion, nor had there been coordinated efforts to identify technologies by which to gauge the performance of these types of projects. Therefore, a key consideration of the plan was to develop a framework to establish a program to identify ITS projects, including needed infrastructure to monitor their performance. The plan took a "start small" approach with its goals, objectives, and performance measures. Proposed projects were in part based on implementing the infrastructure needed to collect data to report performance measures (examples shown in **Exhibit 25** and **Exhibit 26**) supporting its five goals that align with WisDOT corridor management-related goals:

- **Goal A:** Improve safety and security for all transportation system users, operators, and public safety and construction/maintenance personnel
- **Goal B:** Enhance and/or enable multiagency communication, coordination, and data sharing
- **Goal C:** Enhance transportation system efficiency and reliability and reduce its impact on the environment
- **Goal D:** Enhance attractiveness of, and operational support for, alternative transportation modes
- **Goal E:** Preserve the transportation system

WisDOT also takes a 'Monitor and React' approach to its ITS strategies of ramp metering and cross-jurisdictional signal optimization. It is constantly monitoring traffic levels and impacts of traffic operations and will adjust accordingly. If, for example, traffic levels at a particular ramp decrease, metering will be removed until needed.

Exhibit 25 Examples of the Madison Metropolitan Area's Performance Measures Related to its ITS Strategic Plan

Advance System-Wide Efficiency, Reliability, and Integration Across Modes

Performance Measure	Target	Data and Trends	Current Status	Analysis
Transit On-Time Performance *The percentage of Metro Transit on-time buses*	STEADY percentage of on-time buses	Transit On-Time Performance: 2014 – OnTime 84.1%, Late 12.5%, Early 3.4%; 2015 – OnTime 85.0%, Late 11.2%, Early 3.8%; 2016 – OnTime 85.1%, Late 10.9%, Early 4.0%; 2017 – OnTime 88.3%, Late 7.5%, Early 4.2%; 2018 – OnTime 87.9%, Late 8.4%, Early 3.7%	STEADY percentage of on-time buses	Transit system on-time performance is critically important to serve riders effectively. In 2018, Metro Transit maintained the strong performance it achieved in 2017, with 87.9% of buses on time.
Interstate Reliability* *Percent of person-miles traveled on the Interstate considered reliable*	2019 Target: INCREASE ≥ 94%; 2021 Target: INCREASE ≥ 90%	Percent Of Interstate Rated Reliable: 2017 – 100%; 2018 – 100%	STEADY Meets Target	In 2018 100% of the person-miles traveled on the Interstate in the Madison Metro Area were considered reliable by the federal measure, consistent with the previous year. See Maps 10 and 11 in Map Book.
Freight Reliability* *The truck travel time reliability index (TTTR) on the Interstate*	2019 Target: INCREASE ≤ 1.4; 2021 Target: INCREASE ≤ 1.6	Truck Travel Time Reliability: 2017 – 1.09; 2018 – 1.19	DECLINE Meets Target	The freight reliability target measures the efficiency of freight movement on the Interstate. In 2018 the TTTR for the Interstate in the Madison Metro area was 1.19, a 9% decrease in reliability, however still well below the performance target. See Map 12 in Map Book.

The truck travel time reliability index is a ratio between "normal" truck travel times on the Interstate and the "worst" truck travel times. The truck travel time reliability index is reported as the average truck travel time reliability index for all Interstate roadway segments. The higher the truck travel time reliability index, the greater the delay.

*Indicates federal performance measure and MPO adopted targets

11

SOURCE: The Madison Area Transportation System Performance Measures Report, 2018

Exhibit 26 Examples of WisDOT's Performance Measures Related to Madison's ITS Strategic Plan

January 2020

Wisconsin Department of Transportation
MAPSS Performance Scorecard

✓ Goal has been met ↑ Performance is trending in a favorable direction ↔ Trend is holding ↓ Performance is trending in an unfavorable direction

Performance measure	How we measure it	Current report period	Goal	Goal met	Trend	Comments	Date Last Reported
Mobility: Delivering transportation choices that result in efficient trips and no unexpected delays.							
Incident Response Calendar year 2018	Percent of incidents cleared within a specific timeframe	Intermediate incidents: 89.5; Major incidents 83.3	Intermediate incidents: 90.0; Major incidents: 80.0		↑	The department continues to coordinate with agencies to effectively manage and respond to incidents across the state.	1/2020
Winter Response State fiscal year 2019	Percent to bare-wet within a specific time period after a storm	73 for 24-hr roads	70.0 within specified time	✓	↔	The department continues to develop and implement best practices to clear snow and ice as efficiently as possible. The new Brine Technical Advisory Committee is an example of statewide collaboration to develop safe and cost-effective strategies.	7/2019

3.4.9 Corridor “Stop” #3: Minneapolis/St. Paul, MN

Minneapolis/St. Paul is one of the largest metropolitan trade centers in the northern tier of the United States, and a juncture where the I-90/94 system interfaces with the I-35 system. The I-90/94 system and its tributaries connect almost every community and trade center in the region and face complex challenges regarding their alignment, and the role of their supporting arterial systems in accommodating both the national trade traffic from the national corridor system with the role of the supporting arterials in supporting community quality of life and economic vitality. In the first half of the Twentieth Century Rondo Street in St. Paul, MN was the center of a thriving African American neighborhood. The Rondo neighborhood was home to most of the city’s African American residents and Rondo Street was the primary thoroughfare for the neighborhood’s businesses and cultural organizations. Construction of I-94 through the heart of Rondo in the 1960s would forever alter this tightknit community:

> *“The initial expressway plan for the Minneapolis-St. Paul connection was known as the St. Anthony Route, which would follow St. Anthony Avenue (parallel to University Avenue) and extend right through the heart of the Rondo neighborhood. St. Paul city engineer George Harrold opposed this plan--citing concerns about loss of land for local use and the dislocation of people and business--suggesting the alternative Northern Route, which would run adjacent to railroad tracks north of St. Anthony Avenue, leaving the street intact. Ultimately, the St. Anthony Route was chosen and approved by government officials citing its efficiency.*
>
> *In 1955, Rondo community leaders Reverend Floyd Massey and Timothy Howard worked to lessen the effects of freeway construction and gain support for a new housing ordinance through the formation of the Rondo-St. Anthony Improvement Association. Their advocacy was successful in achieving a depressed (below-grade) construction of I-94, however, the route still split the Rondo neighborhood and forced the evacuation and relocation of hundreds of people and businesses. One in every eight African Americans in St. Paul lost a home to I-94. Many businesses never re-opened.“*[75]

[75] “Libguides: Rondo Neighborhood & I-94: Overview,” Overview - Rondo Neighborhood & I-94 - LibGuides at Minnesota Historical Society Library, accessed October 26, 2021, https://libguides.mnhs.org/rondo.

In the wake of the construction of I-94, the Rondo Neighborhood never fully recovered, however, the community vowed to remember and preserve the legacy of a once-thriving neighborhood. In the early 1980s, community leaders decided to celebrate the sense *of community, stability, and neighborhood values of the old Rondo community.*[76] The first "Rondo Days" celebration was held in July 1983 to celebrate the history and legacy of the community. The annual Rondo Days Event attracts tens of thousands of residents, past residents, and visitors to St. Paul each summer.

Rondo and Rethinking I-94

During the Rondo Days Celebration in 2015, MnDOT Commissioner Charles Zelle made a formal, public apology to the Rondo Community for the past decisions and policies that so affected their once vibrant neighborhood. Commissioner Zelle also committed to undertaking a study to examine opportunities to re-engage with the community, repair the trust between the neighborhood and public officials and seek opportunities to re-connect the neighborhood and re-establish the lost sense of place.

The first phase of the *Rethinking the I-94 Corridor* project was completed in 2018. According to Gloria Jeff, MnDOT's Director of Livability, the goal of Phase 1… "*Was to get to know the community. What do they need from the transportation system; how can transportation support job creation and restore/ retain a sense of place in the community."* Ms. Jeff noted that MnDOT is currently working to develop a livability framework to guide future decisions. The framework is based on six critical areas:

- Equity
- Economic impact/Vitality
- Public health
- Sense of place
- Safety/security
- Trust

[76] "Rondo Days: Rondo Avenue, Inc: United States," Rondo Avenue, Inc, accessed October 26, 2021, https://www.rondodays.net/.

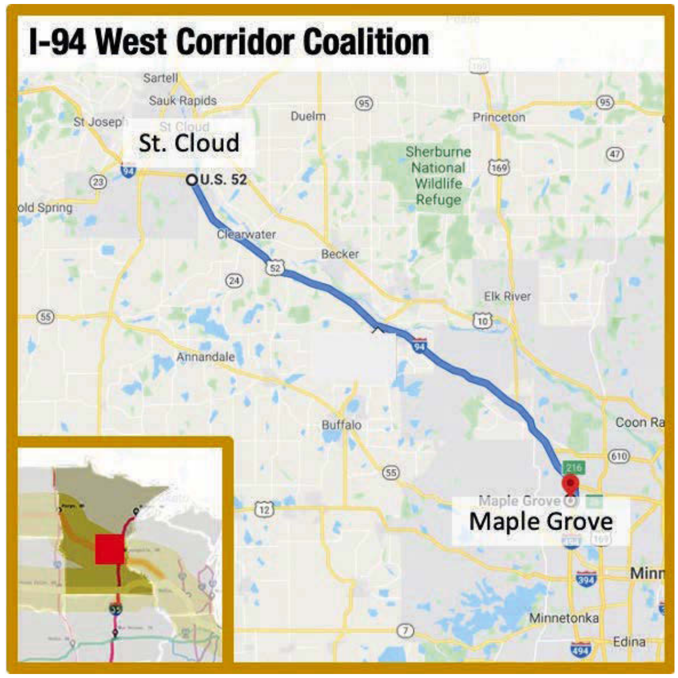
MnDOT recently unveiled plans for an expansive bridge over I-94 in the heart of the old Rondo neighborhood. Proposed pedestrian improvements include enhanced crossings, wider sidewalks, and a gentler slope approaching I-94. An undated courtesy rendering of the new bridge (shown in **Exhibit 27**) was published by the St. Paul Pioneer Press January 10, 2019: [77]

Exhibit 27 Rondo Dale Street Bridge

The performance impact regime for I-94 and in the Rondo area continues to evolve, and will likely be a significant potential beneficiary of the type of tactics offered in the Playbook.

[77] An undated courtesy rendering, circa Jan. 2019, shows a proposed bridge to be built over Interstate 94 at Dale Street in St. Paul. The Dale Street reconstruction project is expected to begin in 2019 with sections of the street rebuilt between Iglehart and University avenues and a bridge over Interstate 94. Pedestrian improvements include enhanced crossings, wider sidewalks and a gentler slope approaching I-94. Ramsey County officials anticipate the bridge will be removed in January 2020 and work will be completed in the fall of 2020. (Courtesy of Ramsey County). "Dale Street Reconstruction," Ramsey County, August 26, 2021, https://www.ramseycounty.us/residents/roads-transportation/current-roadwork/2021-road-construction-maintenance/dale-street-reconstruction; Tad Vezner, "New Dale Street bridge over I-94 will pay homage to old Rondo neighborhood," Twin Cities Pioneer Press, January 10, 2019, https://www.twincities.com/2019/01/10/new-dale-street-bridge-over-i-94-will-pay-homage-to-old-rondo-area/.

I-94 West Corridor Coalition



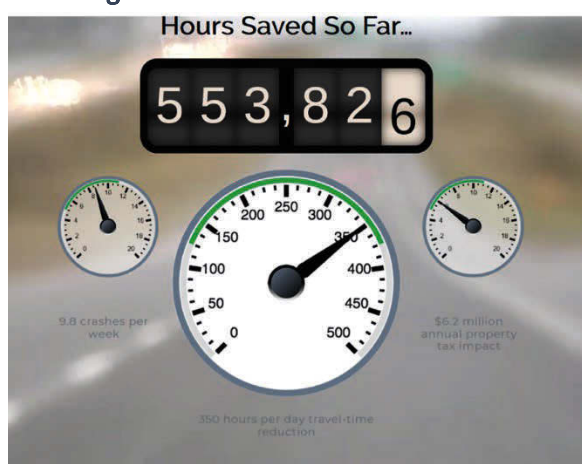
Just thirty-five miles west of Rondo Avenue in St. Paul, a very different grassroots coalition has formed to support re-investment in the I-94 Corridor. The I-94 West Corridor Coalition (94-WCC) is made up of businesses, individuals, and local government agencies to improve travel times through increased capacity along the corridor between Maple Grove and St Cloud, MN (a total length of approximately 45 miles). The corridor utilizes a shared voice to advocate for its goals of enhanced economic development, increased safety, improved quality of life, and improved freight mobility.

In 2013, the 94-WCC successfully lobbied the Minnesota State Legislature to designate I-94 as a "Corridors of Commerce" facility, making it eligible for funding under a special transportation bonding bill to support the construction/reconstruction of key highway facilities in the state. Capacity expansion improvements on I-94 championed by the 94-WCC were included in the initial package of projects funded through the program. Additional improvements were funded in 2015 and 2018.

The 94 WCC has hired a marketing firm to help get their message out: The 94-WCC maintains a website that includes a running scorecard of the benefits from recent investments in capacity expansions and a new interchange in the City of Dayton. The "Greenlight94" home page is shown in **Exhibit 29**. The scorecard provides estimates of time savings (360 hours of travel time reduction per day), reductions in crashes (9.8 per week), and annual property tax benefits ($6.2 million annually).

The 94-WCC has indicated that with the completion of Phase 1 improvements, travel time delays in the corridor were reduced by 55 percent between Rogers and St. Michael. The improvements were also credited with producing nearly 3 million square feet of new industrial development in the local area.

Exhibit 28 **Screen Shot of the I-94 West Corridor Coalition – Greenlight I-94**



3.4.10 Corridor "Stop" #4: Met Council's Integration of Land-Use into Transportation Planning

The Minneapolis-St. Paul metropolitan region's historical development has impacted its transportation system usage. Urban neighborhoods built before the late 1940s still today allow residents to utilize active transportation to reach commercial destinations and public transit services versus more recent suburban neighborhoods are accompanied by increased automobile ownership, single-occupancy trips, VMT, and congestion. However, recent development in the region points to the ability to influence travel demand via land-use policy. Since 2009, more than half of newly constructed housing units have been multifamily along transit-served corridors in both urban and suburban settings. Other positive signs include a 25 percent increase in the number of Downtown Minneapolis residents since 2006, and a decrease in the region's average land utilization rates (**Exhibit 29**).

Exhibit 29 Met Council's Regional Land Consumption Rates

Time Frame	Acres per 1,000 New Residents	Acres per 1,000 New Households
2010 – 2016	91	234
2000 – 2010	291	626
1990 – 2000	261	632

SOURCE: Met Council's Thrive MSP: Transportation Policy Plan, Overview

Thrive MSP 2040's Transportation Policy Plan (TPP), Met Council's most recent long-range planning document, establishes, among other items, land-use policy for the region's future. In it, the Met Council explicitly makes a case for the symbiotic relationship between land-use and transportation. "The effective use of land by people and businesses requires a transportation system to access it. Similarly, land-use drives the need for the transportation system". The plan specifically identifies the ability to impact and manage travel demand via the adoption of particular land-use policies such as compact development, mixed-uses, well-connected street networks.

Land-use plays a prominent role in the TPP. As part of its bold regional vision, it sets out to "Use investments to shape development and respond to how land-use influences travel". Three of the plan's principals involve land-use including the increase of transit service and expansion of the transitway system by supporting the development of housing, shopping, places of employment along transit lines and around stations; including active transportation elements in local comprehensive transportation and land development plans; and balancing the needs of the aviation system with land-use decision. Three of the plan's goals are indirectly impacted by land-use while one is directly related: **Leveraging Transportation Investments to Guide Land-use.** Supporting this goal is a number of strategies and four objectives:

A. Focus regional growth in areas that support the full range of multimodal travel.

B. Maintain adequate highway, riverfront, and rail-accessible land to meet existing and future demand for freight movement.

C. Encourage local land-use design that integrates highways, streets, transit, walking, and bicycling.

D. Encourage communities, businesses, and aviation interests to collaborate on limiting incompatible land-uses that would limit the use of the region's airports.

The plan includes land-use performance measures (**Exhibit 30**). Specifically, the region tracks the inventory of industrial and manufacturing zoned land, and in particular, the percentage of those acres with rail and river access. Met Council notes the important role rail and river transport can play in addressing congestion, the environment, and economic competitiveness as well as the increasing competition for land adjacent to the Mississippi River to be redeveloped into residential and commercial purposes. It also recognizes the need to maintain the roads connecting the rail and river terminals to the major highway system. The plan provides minimum guidelines related to activity level (residents, students, jobs) within a 10-minute walk (1/2 mile) from transitway stations, provides minimum density guidelines for transit corridors for various transit services and community types, and tracks resident and job growth near high-frequency transit service areas. Lastly, Met Council reviews local comprehensive plans for consistency and compatibility with its own.

Exhibit 30 **Met Council Land-use Related Performance Measures**

Performance Measure	Description	Existing Conditions (2015)	2040 No Build	2040 Current Revenue Scenario	2040 Increased Revenue Scenario
Freight Land Use	Total acreage of land zoned as industrial and located on riverfront or with rail access	11,839	Ongoing tracking and reporting		
Population and Job Growth Near High-Frequency Transit Service Areas	Percent of forecasted growth projected to occur within 1/2 mile of high-frequency transit corridors				
	• Percent Population Increase	N/A	13%	19%	23%
	• Percent Job Increase	N/A	24%	34%	44%
Transit-Supportive Policies in Local Comprehensive Plans	Number of communities with comprehensive plans that include transit supportive policies or strategies	Will develop evaluation process as 2018 comprehensive plan update process concludes	Ongoing tracking and reporting		

SOURCE: Met Council's Thrive MSP: Transportation Policy Plan, Chapter 13

3.4.11 Corridor "Stop" #5: MnDOT's Utilization of StreetLight Data for Truck Trips within the I-94 Corridor

The middle expanse of the I-94 corridor is a critical economic artery carrying passengers and commerce between the Great Lakes and the Northern Great Plains. Designated by MnDOT as an Interregional Corridor, it serves as an important commuter route and carries recreational and business traffic. A significant portion of the businesses associated with Minnesota's *Medical Alley*, the medical manufacturing, and medical device industry clusters have formed along the I-94 corridor. The growth in traffic on I-94 on the northwest side of Minneapolis has led to a growing concern from citizens and businesses along the corridor related to congestion, especially during peak hours of travel. In response, MnDOT has planned several projects to increase capacity. To assist in outreach and construction management as these projects advance, the MnDOT Metro District sought a better understanding of the businesses that rely on the corridor, and the commerce that flows through it.

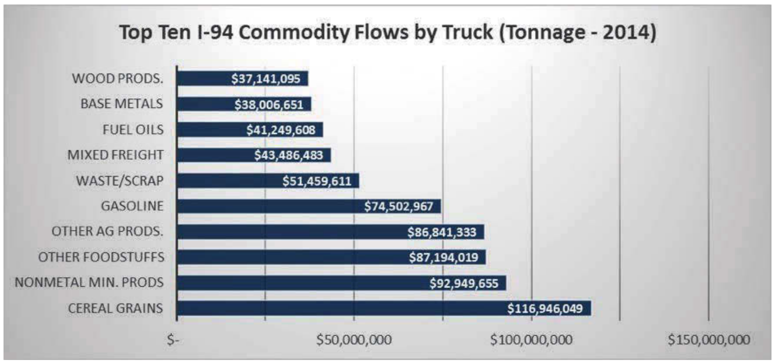
Estimating the Value of Commerce in the I-94 Corridor between the Twin Cities and St. Cloud was a project undertaken by MnDOT's Metro District to characterize the types of truck trips utilizing the corridor. According to John Tompkins, the Metro District's Multimodal and Intermodal Planning Director, one of the goals of the project was *to understand what businesses MnDOT needs to communicate construction activities to*. Mr. Tompkins said that one of his goals is to bring freight stakeholders into the department's operational activities. "*Historically, we have attempted to communicate construction activities in a corridor to commuters and the general public through a variety of outreach activities, but the business community and commercial users have often been overlooked.*"

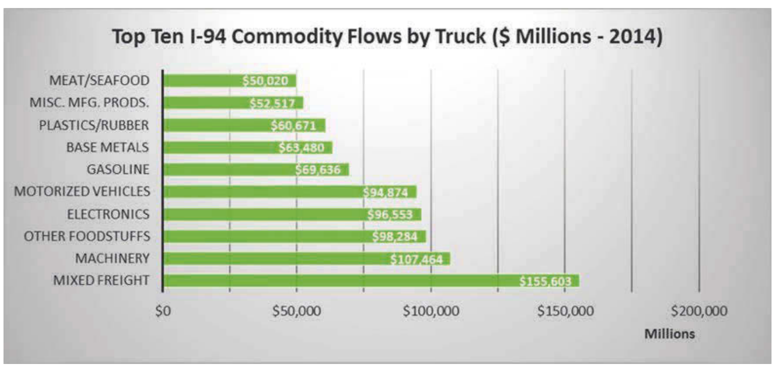
Using StreetLight data, it was estimated that about 40 percent of the truck trips were local to the corridor (trips that both entered and exited the I-94 Corridor via a ramp within the corridor's scope) while roughly 53 percent of the trips either originated or terminated within the corridor's scope. Through truck trips (those that both entered and exited the corridor via a defined entry or exit point and did not stop within the corridor) only accounted for approximately six percent of the truck trips.

The analysis also showed that truck-to-rail transload facilities generated the most StreetLight truck trips using the I-94 Corridor in relation to other multimodal facilities, followed by intermodal rail terminals, rail yards, air cargo facilities, inland river ports, and grain elevators. Trucks utilizing the corridor were almost twice as likely to originate or terminate at a parcel zoned as 'industrial' versus a parcel zoned as 'commercial'.

The analysis also used the Freight Analysis Framework (FAF) from FHWA disaggregated to a county level to examine commodity movements in the corridor. The largest flows of commodity volumes through the I-94 Corridor moving by trucks mirror the flows by all modes led by *Cereal Grains, Nonmetal Mineral Products, Other Foodstuffs, and Other Agricultural Products*. The top commodities by value moving in trucks through the corridor also match the total commodity flows with *Mixed Freight* ranking first followed by *Machinery, Other Foodstuffs, and Electronics*. Using the combined information about truck generating facilities and companies that generated the most truck trips, a list of commercial stakeholders was developed and provided to the contractor conducting public outreach activities to communicate construction activities in the corridor. Specific outreach strategies were also developed, including a Minnesota 511 Trucker App which provides information specific to the commercial vehicle population, such as commercial vehicle restrictions in construction zones.

Exhibit 31 Top Ten I-94 Commodity Flows by Truck





	Truckload (TL, LTL, Partial)	Drayage (container)
Local Trip	$177,873,400	$83,447,731
Outbound Trip	$274,867,454	$34,183,998
Inbound Trip	$259,300,698	$36,069,441
Thru Trip	$294,722,669	-
Total	$1,006,764,222	$153,701,170

Exhibit 33 Cost of draying intermodal containers

The study also used the disaggregated FAF data, merged with proprietary shipment data collected from private businesses. The proprietary dataset contained approximately 15 million bill of lading records that were used to establish average trucking costs for truckload and less-than-truckload shipments by commodity group. This data set was then used to estimate the total annual expenditures by businesses moving commodities via the I-94 Corridor. Shippers spend over $1.16 billion to move raw materials, intermediate goods, and finished products through the corridor, with approximately $1 billion going to truckload and less-than-truckload services. Shippers also spend over $153 million for draying intermodal containers to one of the region's intermodal terminals. The majority of the drayage spend is made by shippers in the seven counties of Anoka, Benton, Hennepin, Ramsey, Sherburne, Stearns, and Wright.

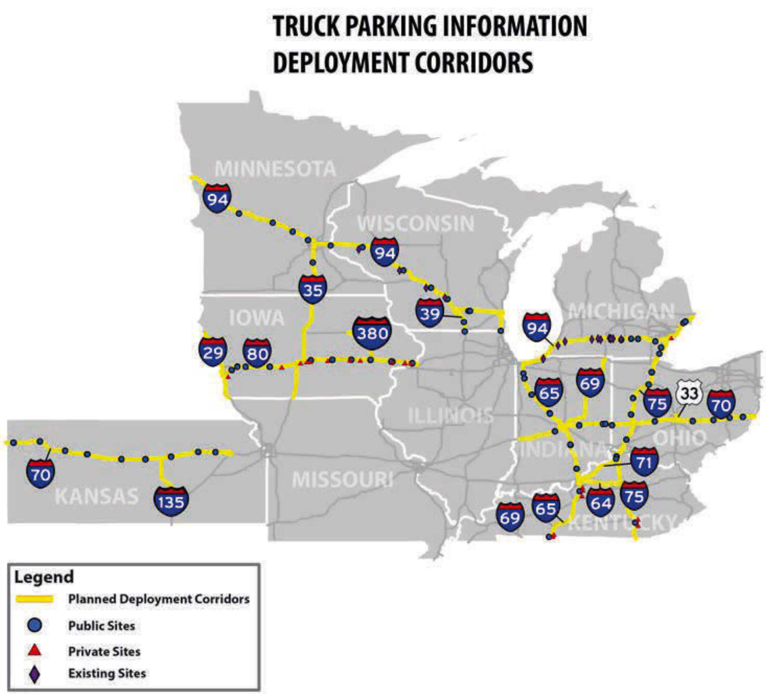
3.4.12 Corridor "Stop" #6: TPIMS Truck Parking System

State DOT's, truck drivers, fleet managers, and owner-operators have faced the issue of truck parking for years. A lack of places to park reduces the productivity of the trucking industry and introduces safety risks to truck drivers and the traveling public due to fatigued driving and parking in unauthorized locations. In 2016, eight states were awarded a TIGER grant to build the Truck Parking Information Management System along major interstate corridors within the Midwest (**Exhibit 32**). The goals of the project were to:

- Improve safety
- Provide timely, reliable information to drivers and dispatchers
- Ensure harmonious and consistent operations between states
- Maximize usage of existing parking
- Add value to the trucking industry
- Implement the system in a sustainable way
- Allow state-specific flexibility

The I-94 Corridor, which travels through four of the eight partner states including Michigan, Indiana, Wisconsin, and Minnesota, was one of the selected freight corridors to build the TPIMS. Other partner states were Ohio, Kentucky, Iowa, and Kansas while advisors to the TPIMS project included the American Trucking Association (ATA), the American Transportation Research Institute (ATRI), the Mid America Association of State Transportation Officials (MAASTO), the Mid-America Freight Coalition (MAFC), NATSO, and the Owner-Operator Independent Drivers Association (OOIDA).

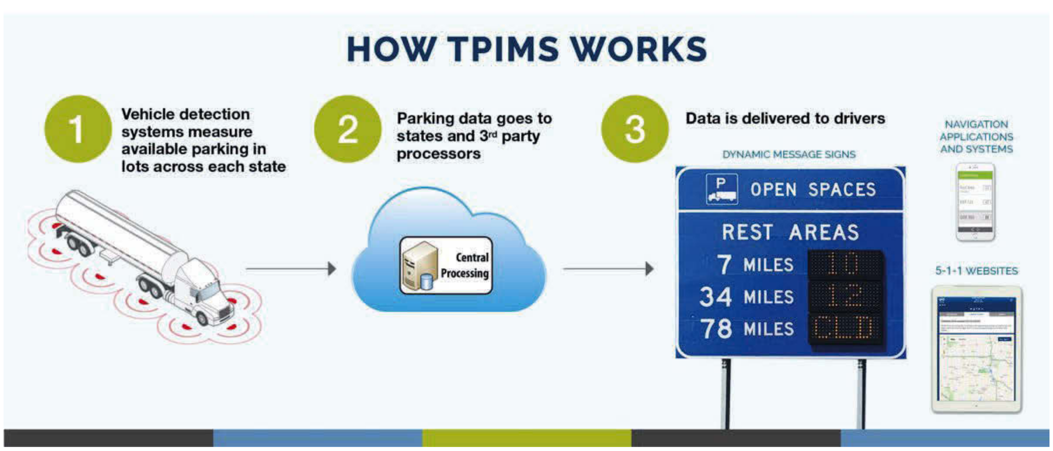
Exhibit 32 TPIMS Network | Truck Parking Information Deployment Corridors



SOURCE: https://trucksparkhere.com/

The system collects data (the available parking spaces) at both publicly and privately managed monitored truck parking lots using state-specific data collection methods and vehicle detection technologies including in-ground sensors, gates, and cameras/video. The data is then uploaded to the states and 3rd party application providers via a public API, and then shared with truck drivers and dispatchers via dynamic messaging signs, 5-1-1 traveler information websites, in-cab navigation systems, and numerous mobile applications. The MAFC serves as the data warehouse to store the historical data records and analyze the system's performance. The project partners anticipate seeing a reduction in fatigue-related truck incidents, an improvement in the efficiency and profitability of freight flows through the corridors, and an overall stronger freight transportation network.

Exhibit 33 How TPIMS Works



SOURCE: https://trucksparkhere.com/

3.4.13 I-90/94 System Takeaways

Based on the research conducted using existing resources and outreach to select representatives of agencies and coalitions along the corridor, the following are some of the key findings:

Corridor Management Means Different Things to Different People (Practitioners): In the State of the Practice report produced for this research effort, it was clear that agency professionals in engineering, planning, and public outreach disciplines have different views of what corridor management means. The in-depth research conducted for the I-90/94 corridor only confirms and strengthens that observation. This I-90/94 case study investigation found an eclectic mix of coalitions from neighborhood coalitions like Rondo, to public/private partnerships like the GNC and I-94 West Corridor Coalition, to the ITS operations coalition of the North/West Passage. Each coalition expressed different perspectives of what corridor management means.

Communication is a Common Theme in Corridor Management Strategies: While understanding that corridor management depends on your perspective – communication is a common thread throughout all management strategies:

- The GNC focused on communicating the economic benefits of a multimodal corridor to political leaders and businesses in the corridor to build a foundation for increased investment in corridor infrastructure.
- The NWP and GLRTOC have focused on communicating traffic and travel information to users of the system. Communicating information and data between coalition partners in real-time or near real-time is also a central tenant of coalition activities.
- Due to the I-94 West Coalition, MnDOT' Metro District undertook a study to identify commercial users of the corridor that should be informed during construction. The value of freight expenditures made by private businesses was also communicated to senior management and politicians to help educate policymakers about the need to keep commerce flowing.
- Finally, the Re-Thinking I-94 Project sought to re-establish communications with a neighborhood devastated by past poor land-use decisions. The underlying purpose of the study was to open communication and build trust to prevent poor decisions from reoccurring in the future.

Corridors Do Not Operate in a Vacuum: David Huft representing the NWP noted that it is difficult to develop multistate data collection and monitoring when the policy and natural environment the corridor operates within is constantly changing.

John Corbin with FHWA in discussing the history of the Gary, Chicago, Milwaukee Corridor Coalition made the following observation: "*How do we as a nation with a weak federal model operate an extremely valuable national resource, the interstate system; and, at the same time incorporate technologies and monitor operations*?... *It is an easier task in China or the European Union which utilizes a strong, top-down approach to coordinate policy and action. What is the institutional model for sustaining commitment amongst shareholders moving forward for collaborative state-based management of the national road network beginning with the interstate system? What should the federal government's, state agencies', and local jurisdictions' roles be?*

The Lack of an On-going Funding Mechanism for Multijurisdictional Corridor Coalitions Hinders On-going Monitoring: Some of the early corridor management efforts examined in the I-90/94 corridor have either dissolved or have been re-formulated for different purposes over time. Some of the coalition representatives discussed data collection activities for their own internal purposes, but few or none were undertaking data collection activities on a multi-jurisdictional basis. The GNC initiated corridor-wide metrics, but when MCOM funding was lost, all available resources have focused on infrastructure investment. NWP collects data and pushes out information to corridor users to support its mission: *The vision of the North/West Passage Corridor is to focus on developing effective methods for sharing, coordinating, and integrating traveler information and operational activities across state and provincial borders.*[78]

Exhibit 34 **I-90 & I-94 System Takeaways**

Topic	Takeaways			
	Strengths	**Weaknesses**	**Opportunities**	**Challenges**
Truck Parking	TPIMS truck parking system across eight states that includes the I-94 corridor in four states (IL, MI, MN, and WI) utilizing publicly available APIs.	TPIM is limited by jurisdictional boundaries to those states awarded a TIGER grant in 2016 and the designated parking facilities.	Expand the system/network across the length of corridors. TPIMS website states: *Cost savings, improved quality of life for drivers, fewer fatigue-related accidents, and better compliance.* No evidence that whether the assumed benefits are being realized.	Since the system only covers a portion of several interstate corridors – other jurisdictions could implement different technology solutions, making data collection and performance monitoring more difficult.
Commercial Vehicle Lanes	Dedicated lanes could offer significant utility in this highly commercial corridor connecting the Midwest to the Pacific Coast.	Dedicated lanes have not been studied in this corridor	May be a good testbed for emerging concepts and technologies. Focused on commercial CAV technologies to benefit supply-chains and their owners	A significant portion of the commerce moving in this corridor moves by rail. In the future, less ice in the Northwest Passage may also create a water alternative
Planning and Environmental Linkage (PEL)	The GNC Coalition completed the formation of an environmental database for the corridor to support future environmental planning initiatives.	There are many coalitions that have formed for a variety of reasons. So, there is no umbrella related to the environment.	The PEL is a relatively new program – so huge opportunities exist to bring local and state governments together	Scenario planning conducted for the GNC SWOT identified the ability to address environmental issues as key to moving trade and commerce initiatives forward.

[78] North/West Passage, "North/West Passage Updated Focus Areas, Issues, Vision, Goals and Objectives," North/West Passage, May 7, 2019, https://www.nwpassage.info/about/strategicplan/.

	Strengths	Weaknesses	Opportunities	Challenges
Corridor Planning and Funding	Several coalitions within the corridor have successfully utilized programs such as the SRP Pooled Funds program and the now-defunct MCOM grant program	The lack of established programmatic multijurisdictional corridor funding programs has resulted in several prominent corridor coalitions falling apart.	There are several states represented in two or more coalitions in the same corridor – suggesting a lack of coordination even among states and less so among state and local governments.	Several coalitions in the corridor have already come and gone due to the lack of programmatic funding support.
Public-Facing Open Data Dashboards	The North/West Passage has established traveler information sites, with an emphasis on commercial truck drivers to keep them informed of inclement weather in remote sections of the corridor	States east of Minnesota do not participate, even though many commercial drivers are headed to/from Chicago or points east, and multijurisdictional efforts suffer from resource (human and financial) mismatch	The NWP traveler information site is a series of links to individual state reporting sites. There is no single site for comprehensive corridor traveler information	A single site for comprehensive corridor traveler information
Corridor Management Hazardous Incidents	The GNC Study examined rail safety and grade-crossing incidents in part due to periodic high-volume oil trains moving in the corridor. Projects that would be funded by federal grants were identified. Ohio DOT has successfully implemented variable speed zones to mitigate winter weather and reduce related incidents.	The U.S. lacks a comprehensive corridor risk assessment program that examines hazardous incidents across modes and jurisdictions.	In part, work on the GNC lead to the development of a grade-crossing assessment tool that was developed under *NCHRP 25-50*. Additional corridors could benefit from variable speed zones to reduce the number and severity of weather-related traffic incidents.	Legislation is needed to grant ODOT the ability to implement the variable speed zones.
Connected Vehicles (CV)/Integrated Corridor Management (ITS)	North/West Passage Coalition has focused on providing better information to commercial truck drivers for nearly two decades. The Smart Belt's public-private partnership provides a best practice.	Coalitions like NWP involve only state-level entities.	Coalition members are looking to Wyoming and lessons learned from the CV project on I-70	Potential reluctance to accept CAVs by the public and mismatched legislation and regulation amongst neighboring states of a corridor.

	Strengths	Weaknesses	Opportunities	Challenges
Performance Measures	NWP is moving toward the creation of a central data collection repository	Research of the corridor found little or no programmatic efforts to monitor corridor performance measures.		
Resilience/Redundancy	I-90/I-94 is a truly multimodal corridor that provides alternatives in the face of disruptions in one mode.	The lack of multimodal planning and funding programs at the federal, state, and local level makes multimodal corridor planning more difficult than need be.		Significant changes to supply chains, i.e. reductions in trade with China and other eastern nations could have a significant impact on the corridor.
Land-Use Initiatives	The Re-Thinking I-94 Project is revisiting land-use issues decades after poor planning decimated the Rondo Neighborhood while the Met Council tracks land-use-related performance measures and leverages transportation investments to guide land-use.	Many corridor management initiatives are parochial and fail to examine larger livability issues.	Livability metrics being developed through the Re-Thinking I-94 project and land-use-related performance measures could become a model for other corridors.	

3.5 Eastern Seaboard (I-95/85) Corridor System

3.5.1 Overview

The Eastern Seaboard Corridor System is defined by the market of I-85 and I-95 from Florida to Maine. **Exhibit 35** illustrates the Eastern Seaboard Corridor System. In addition to the I-85 and I-95 facilities themselves, supporting ancillary corridors and modal systems of varying levels within the targeted geographic focus areas are understood as part of the overall review. The geographic focus metropolitan areas include Atlanta, GA; Richmond, VA; Boston, MA; and South East Florida. These areas are chosen based on random sampling, along with a review to ensure adequate cross-classification of region sizes and characteristics. Several non-metropolitan and inter-regional elements of the corridor system (including rail lines, rural tollways, and other facilities are also profiled in considering the current understanding of corridor impacts).

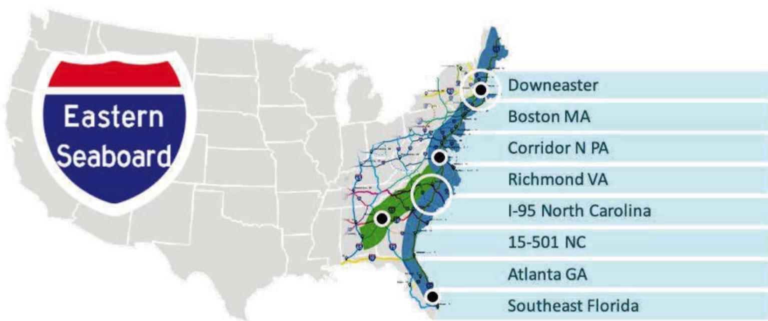


Exhibit 35 **Eastern Seaboard I-95 & I-85**

3.5.2 Active Coalitions and Partners

There is currently an active national I-95 "Eastern Seaboard" Corridor Coalition which is a partnership of over 100 transportation agencies, authorities, and organizations from Florida to Maine. The Coalition began in 1993 with the intent to provide coordinated safety, mobility, and efficiency along the corridor with a focus on testing and monitoring Intelligent Transportation System (ITS) programs. This has evolved over the years to focus on multimodal transport and the efficient transfer between modes. There is also a major focus on coordinating incident management and keeping the communication channels open between public safety officials and transportation officials.

The organization continues to evolve and provides the venue for collaboration among the partners to leverage each other's programs and efforts resulting in the more comprehensive management of the corridor. Agencies can share data, policies, best practices, and lessons learned. The Coalition focuses on three main topics:

- **Intermodal movement of freight and passengers**
- **Coordinated incident management and safety**
- **Travel information services**

Within these focus areas, the Coalition helps plan and coordinate a variety of projects such as a Transportation Systems Management and Operations (TSMO) program, truck parking, connected and autonomous vehicles, and tolling operations.

Outside of I-95, each state Department of Transportation (DOT) is responsible for the corridor management, operations, and maintenance within their state boundary supported by metropolitan and rural or regional planning organizations (MPOs and RPOs). While there are venues for coordination and discussion such as the American Association of State Highway Transportation Officials (AASHTO), Transportation Research Board (TRB), among other professional organizations, there is no formal multistate organization that focuses on the I-85 corridor independently of its role in the wider Eastern Seaboard/I-95 system.

Exhibit 36 below outlines the various agencies that play an active role along the Eastern Seaboard, focusing on three "stops" along the way and their role as it relates to the five metropolitan regions. Findings in this SWOT are reflective of a review of both existing planning documents and interviews held with the Atlanta, Richmond, and Boston MPOs, as well as with FDOT, GDOT, and VDOT.

Exhibit 36 **Partner Roles & Topic Areas**

Focus Area	Active Coalition and Partner	Role of Agency
GA, MA, VA	I-95 Corridor Coalition	I-95 Corridor Coalition for all DOT's, Cities, and MPO's focusing on all modes of transportation
Atlanta, GA (and statewide)	Georgia Department of Transportation (GDOT)	State agency overseeing planning, design, construction, and maintenance of state highways and bridges; Provides planning and financial support of rail, transit, general aviation, and bicycle and pedestrian programs, as well as waterways
	Atlanta Regional Commission (ARC)	Regional planning and collaboration; funding and programming
Boston, MA	Massachusetts Department of Transportation (MassDOT)	State agency overseeing design, construction, maintenance, and operating of state highways, bridges, and tunnels; Provides oversight of rail and public transit, airports, and transportation licensing/registration
	Boston MPO	Regional planning and collaboration; funding and programming
Richmond, VA	Virginia Department of Transportation (VDOT)	State agency overseeing building, maintenance, and operations of all state roadways, bridges, and tunnels
	Richmond MPO	Regional planning and collaboration; funding and programming

3.5.3 Inter-Regional System-Level Indicators and Measures

There are several performance measures currently evaluated within the coalition and its partners to test the performance of the corridor. However, the research found that there are limitations with both the measures and their application.

Along the Eastern Seaboard, the following performance measures (**Exhibit 37**) are widely utilized to test performance, primarily in the areas of operational efficiency, corridor utilization, maintenance, emission reduction, and return on investment (ROI).

Exhibit 37 Performance Measures Used

Used:	Missing:

• VMT Reduction
• Freight Travel Time
• Modal Shift
• GHG Emissions Reduction
• Life Cycle Cost
• Transit Time/Dwell Time
• Generation of Greater Economic Impacts (return on investment)
    • Typically only for freight; sometimes transit
• Crashes
	• Many calculations are only statewide – don't cross jurisdictions, where neighboring jurisdictions use other metrics
	    • Rail Freight analysis did not have this issue
	• Resiliency
	• Economic Impacts
	    • For modes other than freight
	    • Standard rules of thumb for ROI of different types of transportation investment (i.e., roadway widening v. new facility v. different types of transit v. managed lane v. sidewalks v. bike lanes v. beautification, etc.)

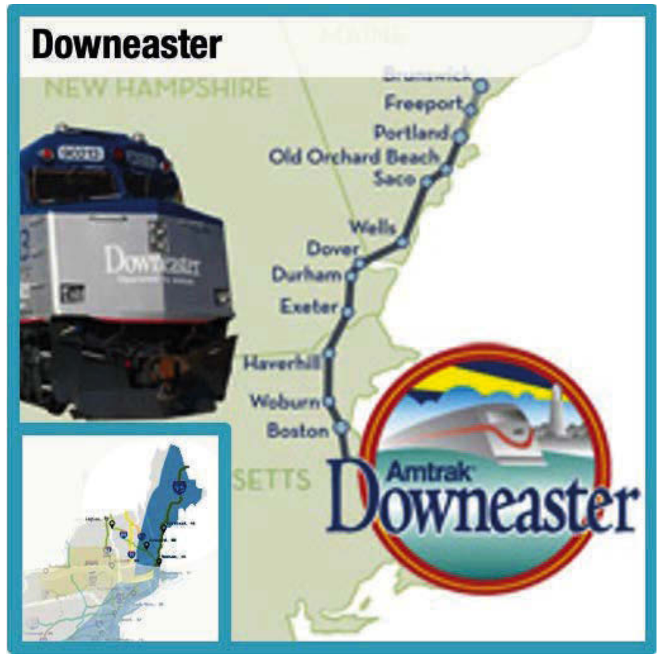
3.5.4 Selected Observations: Metropolitan Areas

Exhibit X illustrates the along the Eastern Seaboard and identifies which of the five focus areas are discussed in the sections below. It should be noted that each of these metropolitan areas has a variety of corridor initiatives. As a result, each stop drills down further into some of the initiatives and others are discussed at a high level as “Other Considerations.” From observations throughout the corridor system, there are specific topics that are explored in detail. They are presented below in Exhibit 38.

Exhibit 38 **Topic Areas by Geographic Area**

TOPIC	GEOGRAPHY								
	Down Easter	Boston MA	Corr. N PA	Richmond VA	I-95 Corr. Coalition	I-95 NC	15-501 NC	Atlanta GA	SE FL
Truck Parking				●	●			●	
Commercial Vehicle Lanes							●	●	
Planning & Environmental Linkage (PEL)	●		●		●	●		●	
Identification of Smart Corridor System					●			●	
Public-Facing Open Data & Dashboards	●	●	●	●	●			●	●
Corridor Management - Hazardous Incidents (Hurricanes, Snowstorms, etc.)	●			●	●	●			●
Connected Vehicles (CV)/Integrated Corridor Management (ITS)				●	●			●	
Performance Measures	●	●	●	●	●	●	●	●	●

3.5.5 Corridor Stop #1: Downeaster



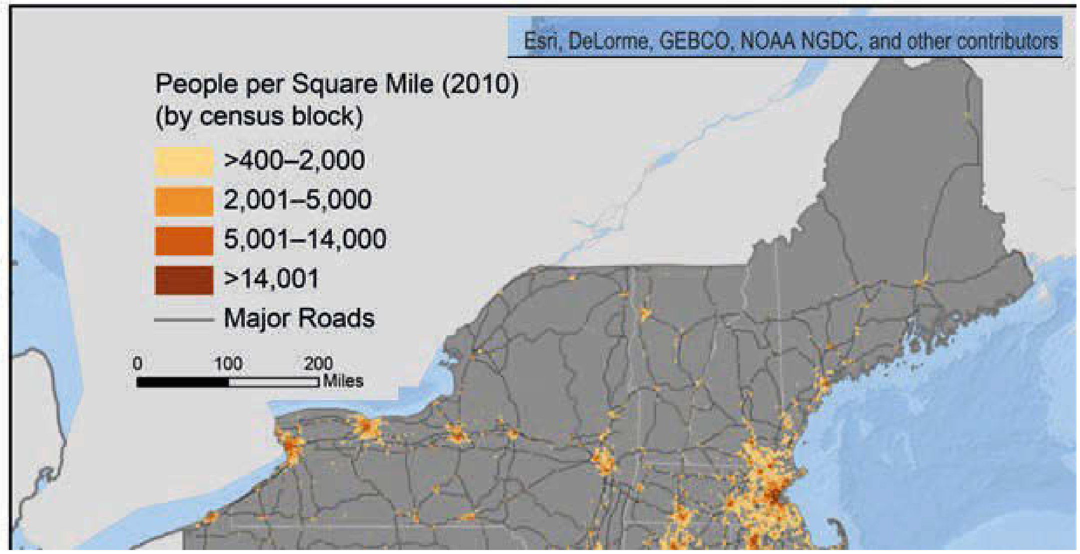
The Downeaster is a 145-mile passenger rail train running from North Station in Boston to Brunswick, Maine, with 10 intermediate stops. The corridor stretches over three states: Main, New Hampshire, and Massachusetts. It runs roughly parallel to the I-95 corridor through Maine, New Hampshire and Massachusetts. Boston is the largest metropolitan area along the corridor and Portland, Maine, the second-largest, which are the main nodes along the network. The Downeaster was the subject of an in-depth case study for both NFCRP 38: *Guide for Conducting Benefit-Cost Analyses of Multimodal Multijurisdictional Freight Corridor Investments* and for *NCHRP 657 - Guidebook for Implementing Passenger Rail Service on Shared Passenger and Freight Corridors.* The case study presented here critically synthesizes and updates the earlier work of these case studies within the context of corridor management impacts, while also providing additional and more recent source material and interpretation from more agency sources.

Transportation activities along the corridor consist of regular and limited access highways; and passenger, commuter and freight rail service. Highways consist of US-1 and I-95. Amtrak provides passenger service ("Downeaster") along the corridor, MBTA provides commuter service from Haverhill to North Station, and Pan Am Railroad provides freight service. Rail service (largely) along what was the Boston & Maine railroad's main line. The route is also designated as a future high-speed rail corridor. Intermodal passenger connectivity consists of park and ride lots and passenger stations. Intermodal freight consists of over a dozen transload facilities. As of 2016, the railroads also connect to the port in Portland, Maine. Passenger flows along the corridor are typically oriented toward Boston, enabling commuters to avoid tolls, gas and parking costs. Truck freight flows are typically northward into Maine, with some limited flows south. Rail freight flows likewise. The only active intermodal terminal is in Portland, Maine. For passenger travel, the corridor connects at the south end to I-93 and to I-295 at the North. Connections to the rest of the passenger rail network require a non-rail connection between North and South stations in Boston, to connect to the rest of the passenger rail network.

There is no grid of roads along the corridor, but rather iterations of roads: inter-town highways and parallel roll roads, and/or US highways paralleled by limited access interstates. Due to terrain, city grids are irregular, reflecting an organic response to terrain and waterways. Main roads are former radial farm highways. The corridor lies primarily in the seaboard lowland physiographic region and temperate broadleaf forest ecoregion, along the Atlantic Coast. Population density (2010) is shown in **Exhibit 39** [79] and is concentrated around Boston.

[79] USGS, "Northeast Population Density," Northeast population density, accessed October 26, 2021, https://www.usgs.gov/media/images/northeast-population-density.

Exhibit 39 **People per Square Mile**



The metro areas of focus along the corridor are Boston and Portland. The Boston Metro area had an estimated population of 4.8 million in 2019; The Portland-South Portland-Biddeford MSA had an estimated population of 535,000. The Boston MSA consists of the agglomeration of a large port city with previously independent villages and towns linked by commuter rail and rapid transit, radiating outward from the central city, with reach further expanded by passenger rail. Historically, this included passenger rail reaching north into Maine.

Exhibit 40 **Downeaster Stops**

Unlike many rail services, congestion along I-95 was not cited as a reason for developing rail service. This is because I-95 in Maine is also the Maine Turnpike; commuting by car from Portland, Maine to Portsmouth, NW would incur approximately a $4 toll in each direction of travel.[80] Instead, the Downeaster train was created in response to the perceived need to restore rail service lost in 1965 to towns that had previously had rail service and an active freight rail corridor. Commuter bus routes connecting the corridor from Boston to Portland existed prior to the advent of rail service. Yet comparable roadway access requires either use of a toll road (I-95) or travel along US-1, which varies in character from the main street of historic towns to exurban strip development to rural highway, suggesting significantly slower speeds.

Collaborative Intergovernmental Management

While operated by Amtrak, the Downeaster is a state-supported service. While owned and administered by the Northern New England Passenger Rail Authority (NNEPRA), the NNEPRA is an agency of the state of

[80] "Tolls," Maine Turnpike Authority, accessed October 26, 2021, https://www.maineturnpike.com/Traveler-Services/Tolls.aspx.

Maine (primarily for liability reasons). During project development, New Hampshire was perceived as lacking interest in passenger rail, with a (suggested) preference for extending the MBTA commuter rail lines into New Hampshire. The NNEPRA contracts with Amtrak for service, which in turn contracts Pan Am Railways (the host railroad) and MBTA for track usage rights and station access. NNEPRA coordinates with Maine DOT and carefully manages revenue and expenses in accord with an annual budget agreed to by the Maine legislature. Responsibility for funding, financing and constructing station platforms were left to the towns, who displayed substantial grass-roots support for the project. Other collaboration included working with initially hostile commercial bus services; experience showed that the availability of more travel options increased ridership for all parties. Collaborating with the host railroad required substantial negotiations (some in bad faith) regarding liability and maintenance costs to the host railroad, which required litigation to demonstrate that "Amtrak can require a host railroad to accommodate increased speeds and the number of trips on an existing Amtrak corridor."[81]

Performance Metrics

The initial struggle to permit operations along the line was to make the upgrades of the railroad track sufficient to permit passenger rail operations with a maximum operable speed of 79 miles per hour. (Freight railroads operate at lower speeds, which requires reduced track quality and permits higher curve radii). Once it became feasible to upgrade the track, the NNEPRA began to work toward improving two metrics: travel time and on-time performance. Improving travel time required improving track quality and eliminating slower sections. As operations continued, improving On-Time Performance (OTP) became an increasingly important metric. The Downeaster continues to work to improve these metrics and to make improvements to the corridor that would permit the addition of additional trains per day.[82] It currently operates 5 trains per day but is unable to add additional trains due to a lack of capacity on the rail line within Massachusetts. The former Boston and Maine railroad mainline is now the MBTA Commuter Rail Haverhill line; the two trains cannot share track because the Downeaster does not make any stops between Haverhill and Woburn—this necessitates the use of a combination of the Haverhill line, the Wildcat Branch and the Lowell line to reach North Station in Boston. Improving these metrics continues to be a struggle:

> *The Downeaster has struggled periodically to provide reliable on-time service primarily due to interference with passenger and freight trains, capacity constraints, speed restrictions, and specific infrastructure deficiencies. The existing infrastructure does not provide enough capacity to add more service to address gaps in the existing schedule, nor does it support speeding up existing or new schedules without eliminating established station stops.*[83]

Like almost all transit systems, a usage metric (ridership) is an important measure of how much the train is used. Ridership is especially important for the Downeaster, as it influences the Farebox Recovery Ratiometric—the Downeaster recovers a higher than average 55 percent of expenditures through fares. Data on performance metrics for the Downeaster are provided in NNEPRA Downeaster Annual Reports.[84]

[81] Alan J. Bing et al., "Guidebook for Implementing Passenger Rail Service on Shared Passenger and Freight Corridors," Transportation Research Board, 2010, https://www.trb.org/Publications/Blurbs/163514.aspx.

[82] Alan J. Bing et al., "Guidebook for Implementing Passenger Rail Service on Shared Passenger and Freight Corridors," Transportation Research Board, 2010, https://www.trb.org/Publications/Blurbs/163514.aspx.

[83] Northern New England Passenger Rail Authority, Service Level (Tier I) Environmental Assessment for the Downeaster Service Development Plan: Boston, Massachusetts to Brunswick, Maine, (Washington, DC: Federal Railroad Administration, 2017).

[84] Northern New England Passenger Rail Authority, Service Level (Tier I) Environmental Assessment for the Downeaster Service Development Plan: Boston, Massachusetts to Brunswick, Maine, (Washington, DC: Federal Railroad Administration, 2017).

The Northern New England Passenger Rail Authority's 2014 TIGER Grant BCA deserves special attention thanks to the use of sensitivity analysis. Rather than supply a single benefit-cost ratio (BCR) or a limited set of BCR scenarios, the application provided a distribution of BCRs under different modeling assumptions. Sensitivity analysis was provided by using Monte Carlo simulation monetizing the costs of Sulfur Oxide (SOx), as well at the 95% confidence interval, as shown in **Exhibit 43**:[85]

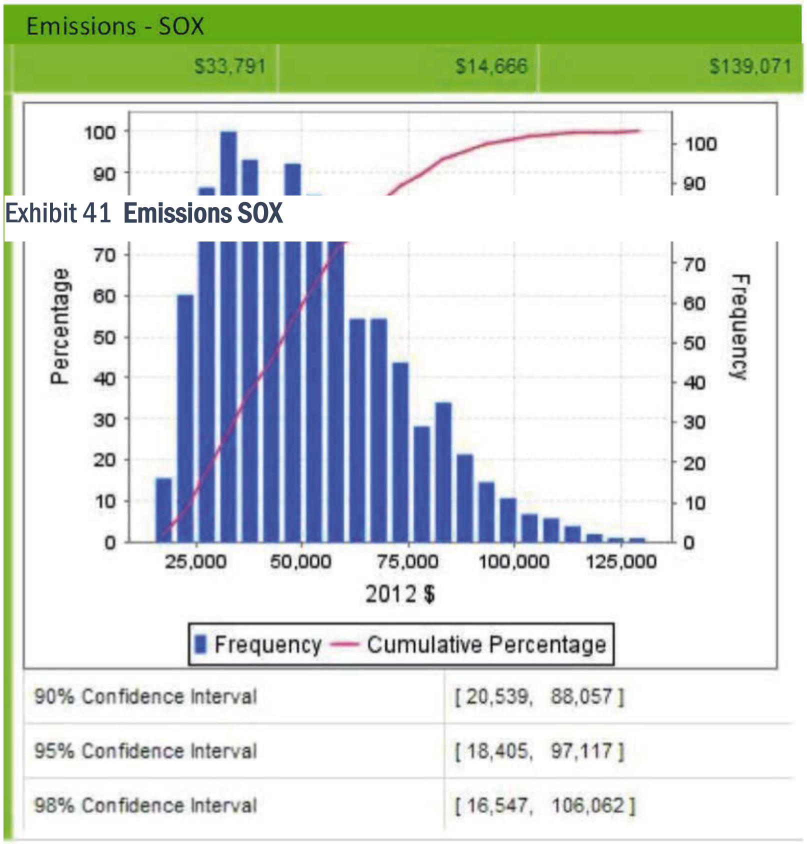


Exhibit 41 Emissions SOX

The economic impacts of the train can be evaluated in terms of rider volumes, business sales, additional visitor spending, and real estate development near stations.[86] The Downeaster Transports over 100,000 annual visitors, with an estimated economic impact of $29m; anecdotal evidence suggests developers value proximity to Amtrak stations, and that substantial development and redevelopment has taken place near stations, encouraging growth and development in downtown areas. Finally, the Downeaster also provides, by way of campus shuttle, connections for students at the University of New Hampshire.[87]

Downeaster Takeaways

Recreating passenger rail service requires making incremental improvements on a range of elements, each reflected with its own performance measurement. While ridership is a function of general performance, there are many aspects of system performance (maximum speed, travel time, on-time performance) that contribute to that goal. A critical factor to measure for passenger rail is the competitiveness of parallel roads; the Downeaster is unique in that its parallel limited access facility is a toll road, such that price (rather than more variable congestion) encourages ridership. While the Downeaster provides service to a wide variety of small towns (many of them tourism destinations), there is little consideration regarding how land-use

[85] Sharada Vadali et al., "Guide for Conducting Benefit-Cost Analyses of Multimodal, Multijurisdictional Freight Corridor Investments," Guide for Conducting Benefit-Cost Analyses of Multimodal, Multijurisdictional Freight Corridor Investments | Blurbs New | Blurbs | Publications, 2017, http://www.trb.org/Publications/Blurbs/175606.aspx; Northern New England Passenger Rail Authority and Patricia Quinn, "Downeaster Service Optimization Project FY2014 TIGER Discretionary Grant Program," Scribd (Northern New England Passenger Rail Authority, April 2014), https://www.scribd.com/document/235748752/NNEPRA-Tiger-6-Grant-Narrative-April-2014.

[86] Economic Development Research Group and KKO Associates, "Economics Benefits Associated with Downeaster Passenger Rail Investments," EBP, February 2005, https://www.ebp-us.com/en/projects/economics-benefits-associated-downeaster-passenger-rail-investments.

[87] "Examining The Economic Impact Of The Downeaster," Great American Stations, February 15, 2017, http://www.greatamericanstations.com/examining-the-economic-impact-of-the-downeaster/.

characteristics (density, diversity of using, walkable design, demographics, etc.) affect ridership. However, thanks to repeated grant applications (TIGER, ARRA, etc.) to improve system operation, the characteristics of the systems service population remain well measured. The lack of land-use consideration may represent a weakness—NNEPRA limits its focus to providing mobility, with minimal considering of accessibility. The Downeaster continues to enjoy opportunities to improve the service, both by expanding the service to new areas, but also by speeding the service through incremental improvements to the track to raise average speeds, and (as a designated High-Speed Rail corridor) the future potential to raise maximum track speeds as well. The Downeaster continues to face challenges in operating an effective service on a minimal budget and is broadly reliant on Federal grants to continue to improve the system.

3.5.6 Corridor "Stop" #2: Boston, MA

The metropolitan Boston area stop focuses on the MPO's new performance measures approach, considering the changing transportation network including technological advances. Boston's view of I-95 and its supporting systems highlights innovative planning work related to corridors, as well as data availability and dashboards. As a large coastal city multimodal port city along the I-95 corridor, Boston experiences significant traffic volumes, congestion, freight traffic, and weather and climate-related impacts. The I-95 facility itself forms an arc along the western edge of the city.

Performance Metrics/Measure

Boston is unique in its new approach to performance metrics and monitoring and the MPO [the Central Transportation Planning Study or (CPTS)] has recently adopted a new set of metrics which it applies to both corridors and other facilities. The MPO developed the *New and Emerging Metrics for Roadway Usage* study in 2019 for the purpose of improving multimodal performance monitoring of the mobility of individual travelers, as opposed to the previous, more traditional approach focused on vehicle throughput.[88] The 24 updated performance measures are shown in **Exhibit 42** and are being incorporated into the MPO's planning documents and processes, including the Congestion Management Process (CMP) and the Long-Range Transportation Plan (LRTP). They include two multimodal measures: 1) Roadway Lane Density, which measures the volume of travelers passing through a corridor in a given timeframe (including transit vehicles but not including bicycles and pedestrians) and, 2) Person Throughput, which is a time-based measure of the number of people attempting to enter a segment or

[88] Ryan Hicks, Seth Asante, and Central Transportation Planning Staff, "Technical Memorandum ," December 19, 2019, https://www.ctps.org/data/pdf/studies/other/Emerging-Metrics.pdf.

corridor during a specific monitoring period, including all parallel transportation facilities, such as sidewalks and bicycle lanes.

Exhibit 42 Boston MPO's Selected Performance Metrics

Selected Performance Metrics

Performance Metric	Mode Measured	Boston Region MPO Goal
Bicycle crashes*	Bicycle	Safety
Bicycle facility continuity (bicycle facility presence)*	Bicycle	Capacity Management and Mobility
Level of traffic stress	Bicycle	Safety
Bicycle rack presence	Bicycle	Capacity Management and Mobility
Proximity to bike network*	Bicycle	Capacity Management and Mobility
Safe crossing opportunities/safe crosswalks per mile*	Pedestrian †	Safety
Sidewalk presence and condition*	Pedestrian	System Preservation/Capacity Management and Mobility
Pedestrian crashes*	Pedestrian	Safety
Vehicle pedestrian buffer*	Pedestrian	Safety
Transit time index*	Transit	Capacity Management and Mobility
Level of transit time reliability	Transit	Capacity Management and Mobility
Person hours of delay per bus trip*	Transit	Capacity Management and Mobility
Vehicle delay per bus run	Transit	Capacity Management and Mobility
Load factor/passenger crowding*	Transit	Capacity Management and Mobility
Safe crossings opportunities at transit stops	Transit	Safety
Truck travel time reliability index	Trucks	Capacity Management and Mobility
Percentage of truck traffic	Trucks	Safety
Buffer time per trip/ total hours of daily truck buffer time	Trucks	Capacity Management and Mobility
Duration of congestion/congested time*‡	Vehicles	Capacity Management and Mobility
Travel time index*	Vehicles	Capacity Management and Mobility
Vehicle-miles traveled*	Vehicles	Capacity Management and Mobility
Average vehicle delay	Vehicles	Capacity Management and Mobility
Roadway lane density	Multimodal	Capacity Management and Mobility
Person throughput	Multimodal	Capacity Management and Mobility

Two, 1- to 5-mile corridors were selected by the MPO for testing the new metrics- Route 16 in Medford and Route 9 in Brookline. Exhibit 43 shows example metrics from the Route 9 test corridor, which reveals that the corridor is poor to average for bicyclists and pedestrians, poor for bus riders, and moderately successful in moving people per travel lane, while truck travel time and reliability is poor.[89] By testing the new metrics, the MPO is able to refine the performance measures if necessary. The MPO is also coordinating with the Massachusetts DOT (MassDOT) on performance measures and looking to expand the use of its new metrics.

[89] Ryan Hicks, "New and Emerging Metrics for Roadway Usage," Boston Region MPO, December 19, 2019, https://www.ctps.org/data/calendar/pdfs/2019/MPO_1219_Emerging_Metrics_Presentation.pdf.

Exhibit 43 **Boston MPO Example Metrics Results for Route 9**

	Performance Metric	Route 9 Eastbound	Route 9 Westbound
Bicycle Metrics	Bicycle facility continuity	40% coverage	0% coverage
	Proximity to bike network	Partial connection	No connection
Pedestrian Metrics	Safe crosswalks per mile	5.0 per mile	5.0 per mile
	Vehicle-pedestrian buffer	1 foot	6 feet
Transit Metrics	Transit time index	1.27	1.35
	Person hours of delay per bus trip	4.03 hours	0.49 hours
Freight Metrics	Truck travel time reliability index	2.45	2.38
	AM total hours of daily truck buffer time	63.25 hours	34.55 hours
Roadway Metrics	Duration of congestion	35 minutes per hour	23 minutes per hour
	Travel time index	2.59	2.01
Multimodal Metrics	Peak hour roadway lane density	716 people per lane per hour	826 people per lane per hour

Good Average Poor

Data Sharing/Partnership and Performance Measure Dashboards

Within the Boston region, the MassDOT and Boston MPO have public-facing data dashboards showing transportation conditions on major roadways. The DOT's Mass511 dashboard shows real-time video, traffic speed information, construction information, closures, and emergency alerts.[90] The Boston MPO's State of the Boston Region Transportation dashboard, while not real-time, contains historical data including, speed index, crashes, bridge condition, pavement condition, sidewalks, bicycle facilities, and demographics.[91] Data are displayed with engaging interactive maps and other visualizations. An opportunity going forward is to update the data with more recent data and incorporate the MPO's new metrics, as it seeks to do in the future.

Planning and Studies

The Boston MPO has undertaken some uniquely innovative planning and corridor-specific planning efforts. The MPO's Long Range Transportation Plan (LRTP) identifies Priority Corridors needing improvement that are critical to regional movement in the MPO. Each year the MPO conducts a corridor study focused on segments of Priority Corridors from the LRTP. Working with the communities where the corridor is located, the studies identify recommendations and assists them through the implementation steps, including obtaining funding

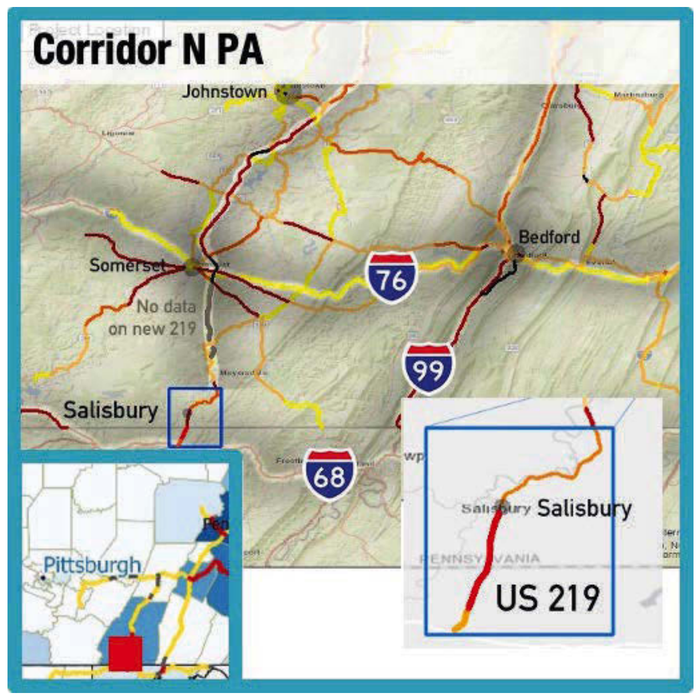
[90] Mass511, "Massachusetts Traffic/Commuter Information," Mass511, accessed October 26, 2021, https://mass511.com/.

[91] Boston Region MPO, "Bridge Condition," Bridges in the Boston MPO Region, accessed October 26, 2021, https://www.ctps.org/dv/lrtp_dashboard/pages/bridges/index.php.

for the projects. Among the selection criteria for the corridors to study is the willingness of the community to champion the projects and see them through to implementation.

The MPO also conducts periodic before and after evaluations of its Transportation Improvement Program (TIP) projects. These studies assess the benefits and negative impacts of projects and provide useful information for comparison of pre-project projections and post-construction conditions. Evaluation is currently underway for the FFY 2020 TIP, including a sampling on TIP projects.[92] The MPO plans to use its new performance metrics in these and other plans and studies. However, they have observed that in many cases, the before data may be difficult to obtain or unavailable.

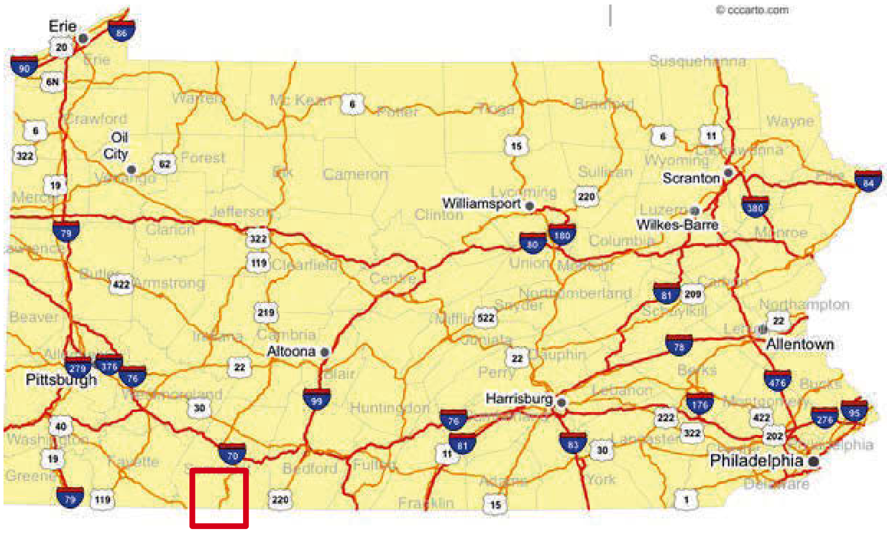
3.5.7 Ultra-Corridor "Stop" #3: "Corridor N" US 219 in Pennsylvania



US 219, labeled as "Corridor N" by its role in the Appalachian Development Highway System, and connects remote areas of Pennsylvania, West Virginia and Virginia to the I-95 system through the supportive I-76 and I-70 east-west connections. It is of interest because (1) it demonstrates the challenges of demonstrating the performance needs and impacts of a low-volume rural corridor in a system where seasonal peak-incident traffic challenges mobility far more than recurring congestion, (2) it is a corridor whose management involves multiple states and planning entities as well as the Appalachian Regional Commission (ARC) and provides an example of a corridor in an area where sparse system connectivity in a given direction (north-south) is more of an issue than overall capacity. There is a strong focus on the efforts of coalition partners in southeastern Pennsylvania communities surrounding Meyersdale for completing the final envisioned section of the ADHS link. The overall link identified by ADHS is approximately 55 miles long, with only the southernmost section (at the West Virginia Border) awaiting completion/upgrade. The nearest major metro area is Pittsburgh, approximately 70 miles west. It is signed as US-219. Corridor N runs roughly parallel to I-99, to which it is west of. The southern terminus is I-68, and its northern terminus is US-86 in Carolltown (near Salamanca). The corridor intersects with I-80 in Dubois. It also intersects I-76 and US-30.

[92] Boston Regional MPO, "Federal Fiscal Year 2020 Tip Project Impacts: Before-and-After Evaluation," March 5, 2020, https://www.ctps.org/data/calendar/pdfs/2019/MPO_0305_Work_Program_TIP_Before_and_After_Studies.pdf.

Exhibit 44 Location of Corridor N



Corridor N is part of the Appalachian Development Highway System, which was created by Congress to provide growth opportunities for the residents of Appalachia who had been bypassed by Interstate Highways due to the cost of building roads in such rugged terrain.[93] Corridor N is the only limited access highway nearby to a large number of small towns laid out with walkable scale street grids such as Salisbury, Meyersdale and Somerset. There is a passenger rail station in Johnstown, PA along with a small Norfolk-Southern train yard. Johnston was the eastern end of the Western Diversion, part of the historic state canal system.There is a CSXT freight rail line that runs roughly parallel to the corridor. Major truck freight flows run east-west along I-70.[94]

The physiographic region of the corridor is the Appalachian Plateau, in the Allegheny Plateau zone. The area is higher in elevation than the area further east. Corridor N is higher in elevation than the surrounding area, in a mountainous district, and characterized by signs of past glaciation. It is predominantly rural, forested and agriculture in character, with Johnstown being the densest population center along the corridor. Coal mining, steel making, light manufacturing and agriculture supplied the economic base. The current economic revival is based on health care, recreation/tourism, manufacturing, education, and warehousing. During the canal age, the portage railroad connected the eastern and western canal systems of Pennsylvania, before more extensive railroading made the canals obsolete.

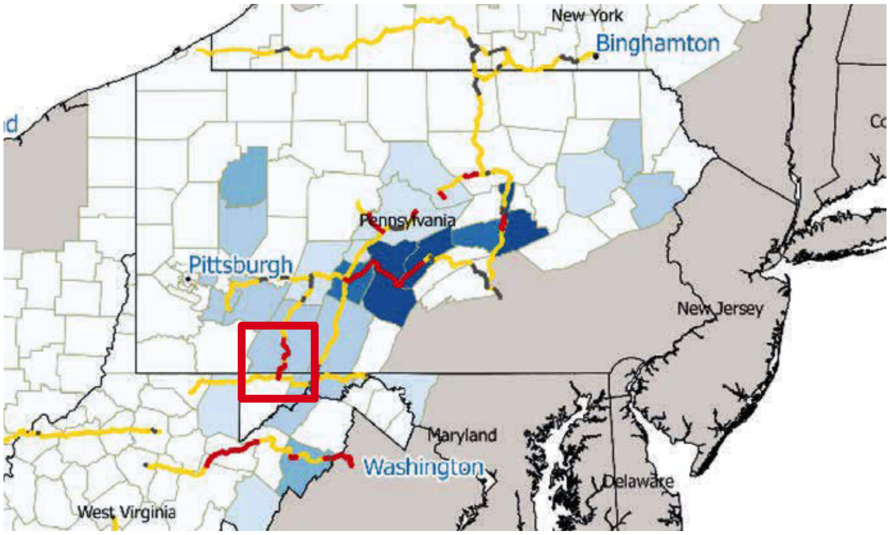
Corridor Impact Metrics

Unlike many urban corridors, the benefit of the project is not reducing travel time through congestion relief. Rather, the focus of Appalachian Development Highways is to bolster economic growth by increasing the connectivity of the region. Corridor benefits rely less on volumes of traffic than on increasing the accessibility of the region. Specifically, US-219 links Appalachia to the rest of the United States and Canada. Regionally, it provides a 4-lane connection between I-68 and the Pennsylvania Turnpike, north of which it connects to US-222 via the Turnpike, it connects to Pittsburgh and I-80. Thus, the corridor impact metrics are both social benefits and economic impacts. This is primarily accomplished by increasing labor force accessibility. The following graphic illustrates anticipated changes due to corridor improvement at the buildout of the Appalachian Development Highway System.

[93] Appalachian Regional Commission, "Appalachian Development Highway System," Appalachian Regional Commission, June 28, 2021, https://www.arc.gov/program_areas/AppalachianDevelopmentHighwaySystem.asp.

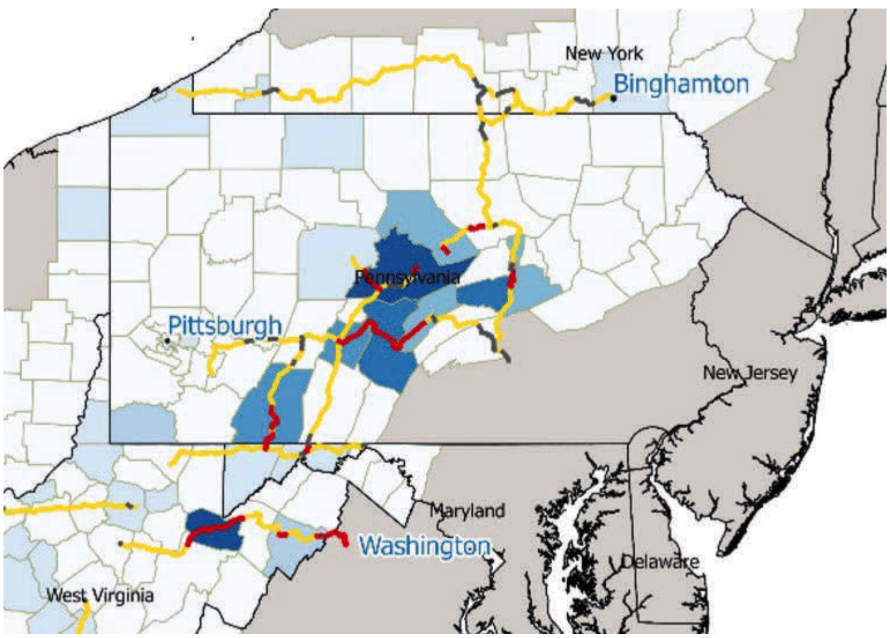
[94] USDOT FHWA, "Major Flows by Truck to, from, and within Pennsylvania: 2012 and 2045," Pennsylvania Truck Flow - Major Flows by Truck To, From, and Within Pennsylvania: 2012 and 2045 - FHWA Freight Management and Operations, accessed October 26, 2021, https://ops.fhwa.dot.gov/freight/freight_analysis/state_info/pennsylvania/truckflow.htm.

Exhibit 45 **Workforce Density**



In addition to social benefits, the effects of the US-219/Corridor N can be measured in terms of supply chain access gains, as it permits the region it traverses to become linked with the large US economy, as shown in the following graphic:

Exhibit 46 **Supply Chain**



Quality roads reduce the "friction of distance." Reduced travel time aids economic integration. Quality, well-maintained roads reduce vehicle operating costs and improve travel time while improving safety for travelers, and thereby increasing reliability along the corridor. The combination of improved reliability and reduced travel makes regions along a corridor less of a backwater, and hence a more attractive location to do business in. Even comparatively remote locations are effectively brought closer together by reduced travel times. Converting two-lane rural highways into limited access four-lane roadways reduces oftendeadly head-on collisions, which reduces delays resulting from accidents. Wider road shoulders make it possible to pull off to the side of the road without blocking travel lanes.

Exhibit 47 **Economic Impacts of building a 4-lane Corridor N**

Category of Value	As of 2025	As of 2035	As of 2045
Vehicle Operating Cost	$48.2	$59.7	$212.5
Travel Time	$259.1	$319.0	$1,128.1
Reliability Time	$72.4	$89.8	$321.0
Safety Costs	$29.8	$36.4	$127.9
Environmental Cost	$6.9	$10.4	$45.7
Shipper/Logistics Costs	$42.6	$54.7	$201.4
Market Access (productivity gain only)	$128.1	$230.0	$248.9
Total	**$587.1**	**$799.9**	**$2,285.6**

US-219/Corridor N also demonstrates how to leverage relatively new data sources: StreetLight, INRIX and HERE data. By using the GPS present in smartphones, vehicle speeds can be estimated on almost any corridor, making it possible to quantify delay previously available only to expensive installed Intelligent Transportation Systems. While not available in real-time, the existence of longitudinal data makes it possible to make aggregate comparisons over time, as shown in the following graphic:

Exhibit 48 **Hours lost to network interruptions and inefficient flows**

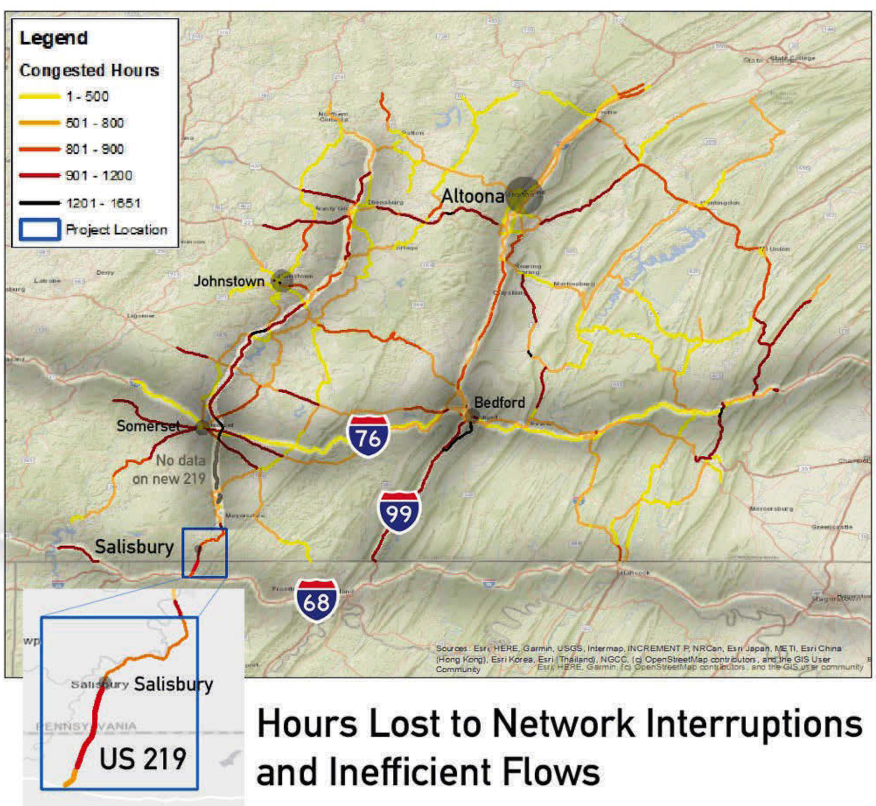
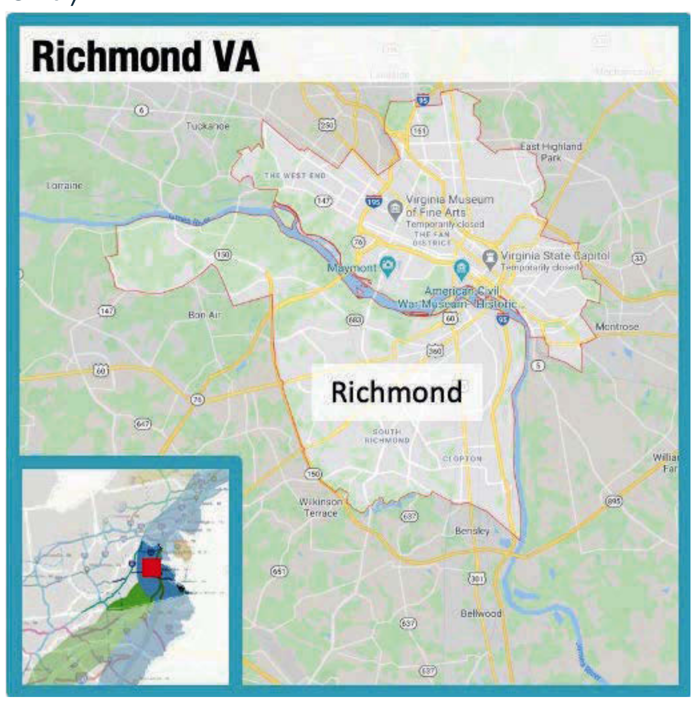


Exhibit 48 illustrates the significant challenges in north-south capacity for peak/incident events on an otherwise low-volume network of rural highways. In particular, the exhibit demonstrates that both I-99 and US 219 as north-south facilities provide some of the only connections to both I-68 and I-76, and both lose significant hours per trip to non-recurring system interruptions when compared to north-south facilities further north or east-west facilities. The Southern Alleghanies Development and Planning Commission (SAPDC) is currently undertaking a study to quantify further the relationship between annual and multi-year incident-peak and recurring seasonal demand as well as available Hazardous Material and emergency routing in relation to north-south capacity on the system; access to the larger Interstate and multimodal network and the impact on the region's business environment. The study will be developing the business case for the corridor in relation to these factors, which often bias corridor investments against rural and sparsely traveled corridors.

Takeaways from US-219/Corridor N

New data sources offer a new and exciting way to look at all corridors, including corridors where data was otherwise lacking or unavailable. The longitudinal nature of data from Streetlight and Here make before and after comparisons simple, presenting an opportunity to not only forecast but validate expected economic development benefits. These benefit metrics can be used to construct a narrative and provide an empirically based benefit-cost analysis to support it.

3.5.8 Corridor "Stop" #4: Richmond, VA



Richmond, VA is in the middle of the Eastern Seaboard and is the convergence of I-85 and I-95. While it is not as large a city as many served by the corridor, the Virginia Department of Transportation (VDOT) and the Richmond MPO (PlanRVA) are making strides to be leaders among the Eastern Seaboard regarding corridor management. This stop highlights three primary management strategies as best practices: corridor planning and funding, incident/event management, and data sharing and dashboards.

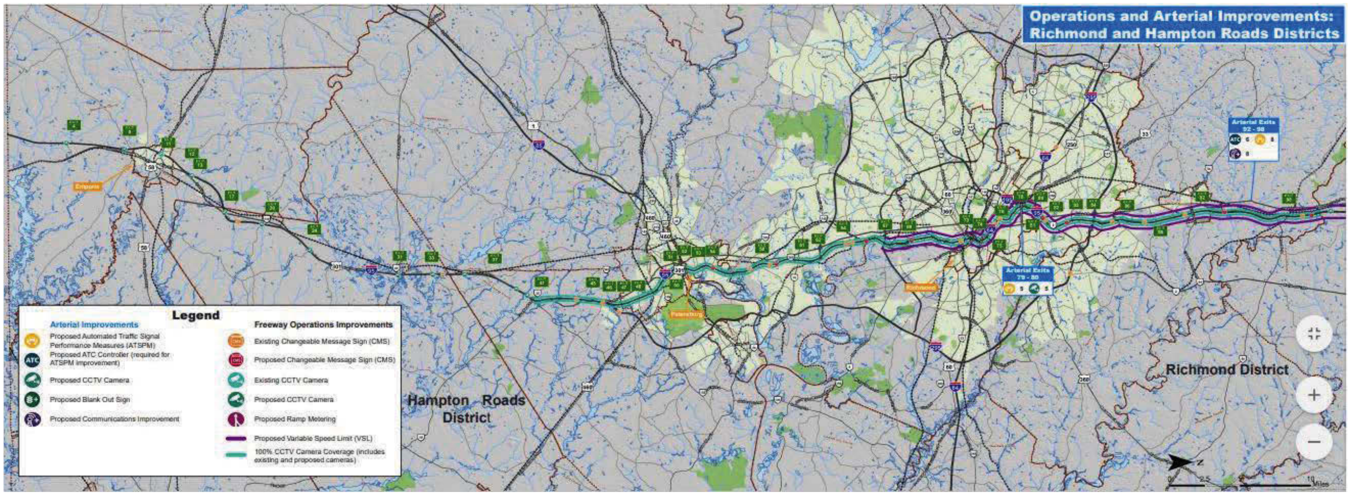
Corridor Planning and Funding

Virginia's state leadership asked VDOT to begin focusing on corridors as a whole (as opposed to segments) beginning in 2018. They wanted to understand the function, efficiency and needs from state line to state line. The first Corridor of Regional Significance Study was I-81 from Bristol (Tennessee state line) to Winchester (West Virginia state line). This study was approved by the Commonwealth Transportation Board (CTB) in December 2018.[95] The I-95

[95] "I-81 Corridor Improvement Plan," Virginia Commonwealth Transportation Board, accessed October 26, 2021, http://www.ctb.virginia.gov/projects/major_projects/i-81_study.asp.

Corridor Study began shortly after that and is currently underway.[96] The purpose of these studies is to assess the existing conditions of the entire corridor, identifying operational and safety needs in specific areas, evaluating both urban and rural needs rather than a "one-size fits all" approach. The I-81 corridor identified $2 billion worth of capital and operational improvements for the corridor.

Exhibit 49 **I-95 Corridor Plan Proposed Operations and Arterial Improvements**[97]



These studies look at a variety of issues from operations, to multimodal access and throughput and bridge improvements. While these studies sound like other corridor plans across the nation, what makes them different is the holistic approach of evaluating a corridor the entire length of the state, documenting unique characteristics and needs along the way. What is also unique to Virginia is this approach gained state leadership attention and during the 2020 state legislative session, the House and Senate passed House Bill 1414 (identical to Senate Bill 890) called the Interstate Enhancement Program. According to Virginia's Legislative Information System, this bill dedicates new state transportation funding (through motor fuel tax and highway use fees for alternative fuel vehicles) to operational and capital improvements specific to corridors with an approved Corridor Study by the CTB.[98]

Corridor Incident Management

VDOT is leading the Eastern Seaboard states regarding incident management, being proactive in managing incidents, weather, and events to ensure the efficient operation of its corridors. As a part of the Corridor Studies, they identified an alternate route for every segment of the I-81 and I-95 corridor throughout the state of Virginia, meaning they have a course of action ready for anything that may hinder traffic movement on I-95. Furthermore, their approach to each corridor varies depending on the characteristics and operations of each. For example, VDOT noted that I-81 is a rural highway with steeper terrain and high truck volumes compared to I-95, which is more urban on the northern end with more passenger vehicles and the

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96 "I-95 Corridor Improvement Plan," Virginia Commonwealth Transportation Board, accessed October 26, 2021, http://www.ctb.virginia.gov/projects/major_projects/i-95_study.asp.

97 "Operations and Arterial Improvements ... - Ctb.virginia.gov," accessed October 26, 2021, https://www.ctb.virginia.gov/projects/major_projects/easset_upload_file29251_141080_e.pdf.

98 Richard L. Saslaw et al., "SB 890 Transportation; Amends Numerous Laws Related to Funds, Safety Programs, Revenue Sources, Etc.," Legislative Information System, accessed October 26, 2021, https://lis.virginia.gov/cgi-bin/legp604.exe?201%2Bsum%2BSB890S.

southern half is similar to I-81 but not as much terrain. These feed into the specific incident management strategies and performance measures. One consistency with the corridors, however, is that VDOT has identified an alternative route for each segment along the corridor. In an interview with VDOT, they noted that most of their arterial alternatives run parallel with the Interstate and are in most cases four-lane divided roadways, ensuring that the incident does not move the congestion to local, small-town roads, but rather onto facilities that can operate with larger volumes. Similar to GDOT, VDOT is currently working with Waze to incorporate these alternative routes into its navigation system. Currently, Waze determines a route based on shortest distance, moving people onto routes that VDOT has not designated as an alternative route.

The following outlines the incident management strategies and performance measures that VDOT monitors in real-time.

Incident management strategies:

- **Dynamic message signs**: Overhead message boards that can notify motorists and trucks of an incident ahead with estimated travel times to bypass incident and/or alternate routes
- **Towing incentive programs**: VDOT provides monetary incentives to two truck companies who respond to incidents within a short amount of time
- **Instant towing dispatch**: As soon as an incident is reported or identified, VDOT will dispatch towing vehicles at the same time as first responders to help ensure the towing vehicle can get through the building traffic
- **Incident Management Coordinators**: Their responsibility is to respond to the scene and has the knowledge of who is needed at the site based on the type of incident. For example, if the incident includes a truck carrying hazardous materials, the Incident Management Coordinator would contact a hazmat team to respond to clean-up

VDOT uses a variety of data and tools to monitor the performance of corridors and more information is below regarding operational performance, but for incident management, VDOT has built a tool for incident performance and measures the following:

- Time to Clear
- Work Zone Hours
- Weather Events[99]

To collect data, VDOT is implementing more traffic cameras along their corridors; however, due to funding constraints, cameras cannot be located everywhere across the state. Therefore, they conducted a crash hot spot analysis for each of the corridors to identify areas with higher crashes and installed traffic cameras in those locations (where they did not already exist) to receive real-time incident reporting.

Exhibit 50 Incident Management Monitoring

[99] Patricia Hall, "Beyond a Touch-a-Truck: VDOT Incident Management Open House," Fairfax Family Fun, October 26, 2019, https://www.fairfaxfamilyfun.com/vdot-hosts-annual-incident-management-open-house.html.

Data Sharing/Partnership and Performance Measure Dashboards

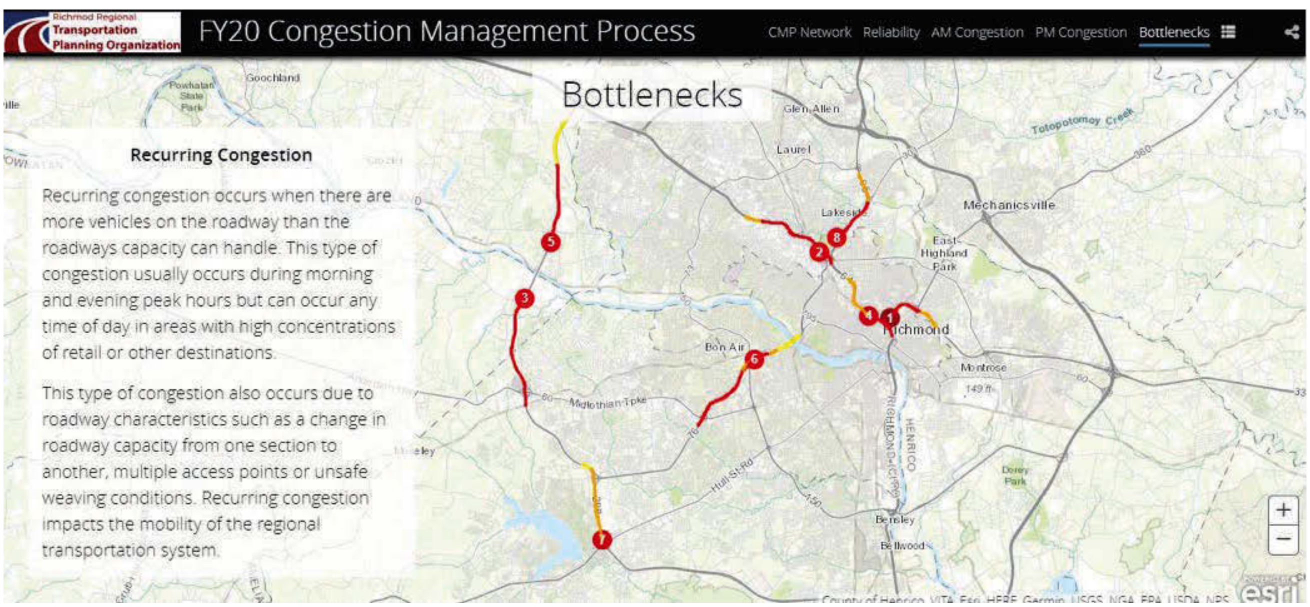
In a review of all the Eastern Seaboard states and cities in this case study, most DOTs and MPOs use similar data sources for corridor performance measures. However, VDOT and PlanRVA have a unique partnership for data sharing. PlanRVA has limited capacity and funding to collect their own data as compared to larger MPOs. As a result, they have developed a process of leveraging available data. VDOT collected a variety of data from sources such as INRIX, RITIS and NPMRDS and conducted some post-processing so that it may be utilized by PlanRVA and others to use for specific needs. PlanRVA then takes this data and applies it to the MPO's needs for their Congestion Management Process, as required by federal regulations.

Specific performance measured used by PlanRVA include:

- Travel Time Index (TTI)
- Level of Travel Time Reliability (LOTTR)
- Truck Travel Time Reliability (TTTR)

From this information, they can process the data using Probe Data Analytics to determine segment congestion during AM and PM peak periods. They also calculate a Planning Time Index (PTI) which tells motorists how much additional time they should add to their trip to account for congestion. PlanRVA displays this data in an interactive Story Map using GIS data to clearly explain these performance measures and what they mean to the public.[100]

Exhibit 51 PlanRVA FY20 Congestion Management Process Bottlenecks



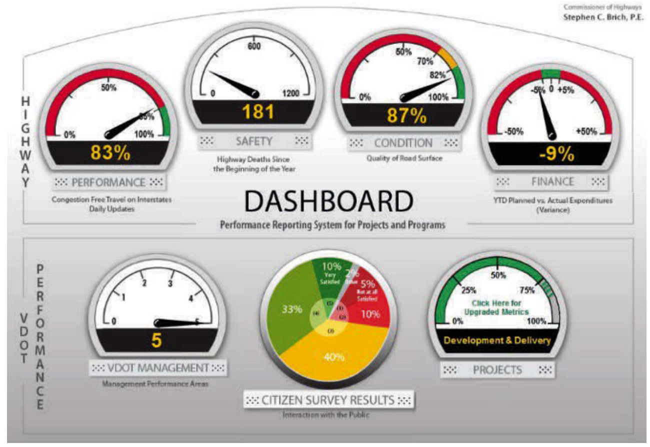
Whereas PlanRVA uses the data to drill down into specific corridor and segment information, VDOT uses the same input data to create a dashboard for their overall system performance. It is interesting to note that the

[100] Richmond Regional Transportation Planning Organization, "FY20 Congestion Management Process," FY20 Congestion Management Process, accessed October 26, 2021, https://arcg.is/0Wfi5.

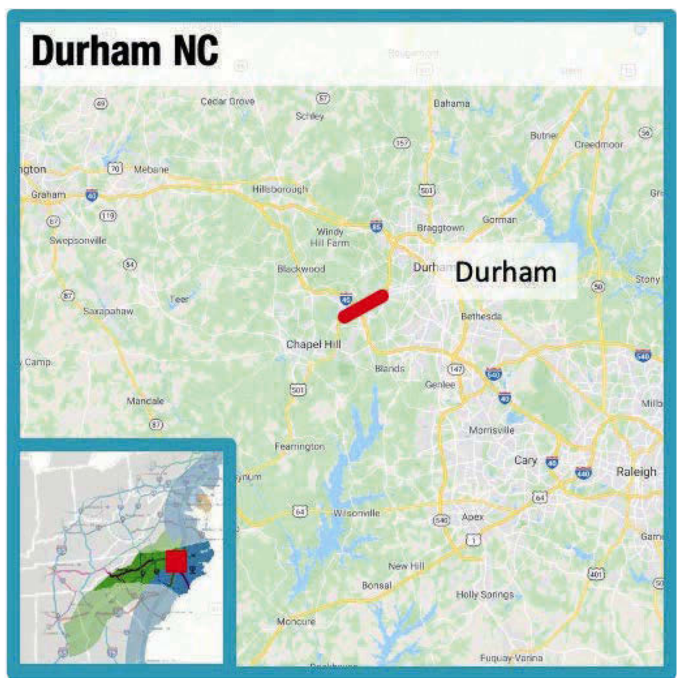
data sources can be scaled to fit specific needs, and this is a strategy that could be used by other DOT and MPO partnerships for more consistent performance reporting.

VDOT has reported on performance measures for several years and maintains a dashboard available with real-time updates. **Exhibit 52** is an example of their dashboard interface

Exhibit 52 VDOT Performance Measures Dashboard[101]



3.5.9 Corridor "Stop" #5: 15-501 in NC



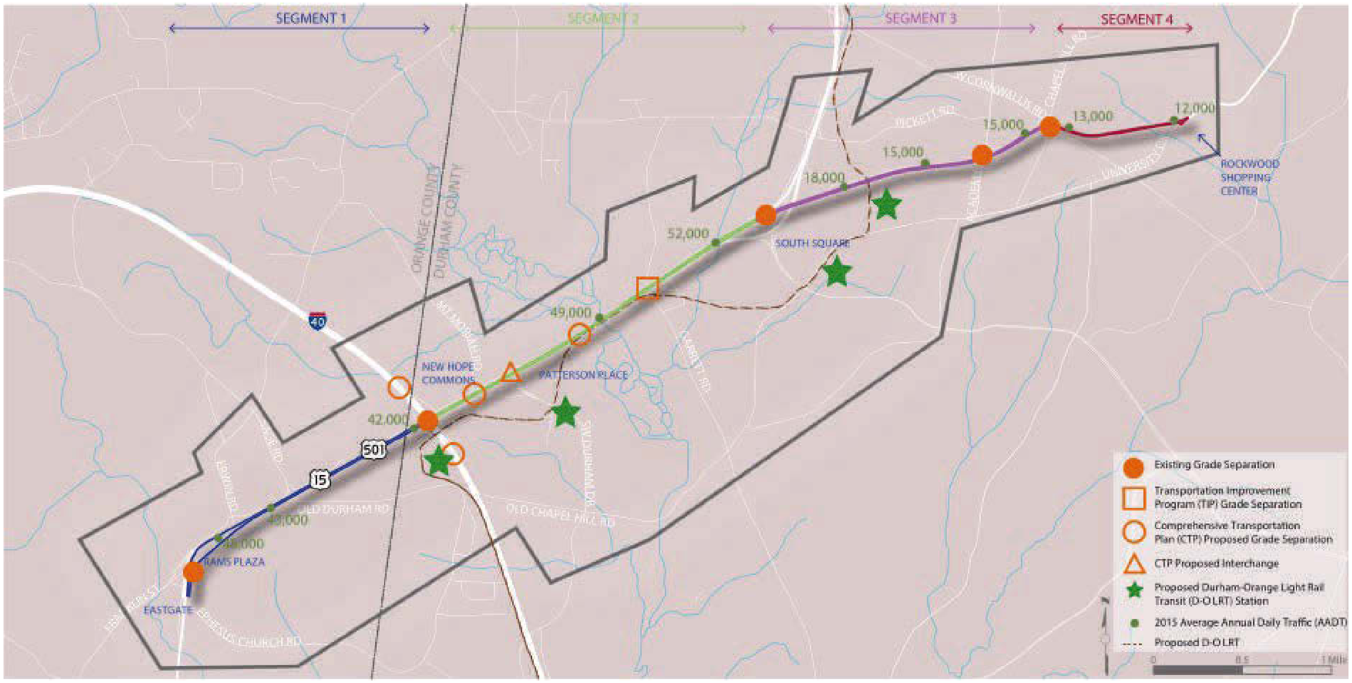
The 15-501 project lies within the I-95/I-85 corridor system, south of whereby I-85 intersects serves the academic and knowledge economy hubs of both Durham, NC (Duke University) and Chapel Hill, NC (UNC-Chapel Hill) – connecting them both to the larger I-85/85 system and to research triangle park. Following the discontinuation of planning for a Durham to Orange light rail, there was a recognized need to "identify a new alternative that would accommodate high-capacity transit within the US 15-501 corridor and improve bus access at key destinations."[102] The proposed project consists of bus-only lanes along with the corridor, with access to key development nodes. It stretches from the southwestern edge of Durham to the southeastern edge of the University of North Carolina (UNC) Chapel Hill Campus. It relates to the bigger corridor system at large through the arterial distributor network of that system, and the competition for users along that system. Arterial roadways feed larger interstate highways, but arterials are often creates by upgrading rural highways rather

101 "VDOT's Transportation Performance Program," VDOT Dashboard, accessed October 26, 2021, http://dashboard.virginiadot.org/.

102 DCHC MPO, "US 15-501 Corridor Study Report Summary," January 2020, https://www.dchcmpo.org/home/showpublisheddocument/916/637489616311400000.

part of a planned roadway grid. Hence, they are often the only through route between two points. Correspondingly, as the most highly trafficked route, they tend to accumulate roadway-oriented commercial characterized by a high number of curb-cuts. Over time, as traffic volumes rise, there is tension along such roads between the mobility and access roles of the road—between providing capacity for through trips and providing access to parcels adjacent to the roadway.[103]

Exhibit 53 15-501 **Grade separated intersections**



Once urban development reaches sufficient density to support fixed-route transit, a further tension arises between the need to serve automobile and transit service demands. Richly lined with commercial frontage, many arterial streets attract a significant number of transit trips. Yet side-running transit operations conflict with both the mobility and access capacity of streets, while the curb cuts and wide roads conflict with safe transit operations and walk to transit access. Automobile and side-running transit like buses impede each other at intersections, resulting in congestion and delay for both. For transit, the effect is especially severe for services intended to use the mobility provided by the roadway, traveling between the destinations the original highway served, rather than to destinations along the highway. The same characteristics that make the corridor attractive to other modes also make it attractive to cyclists. The 15-501 project demonstrates an effort to reconcile these tensions through the installation of center-running dedicated lanes. The roadway is anticipated to reach capacity, even as further dense commercial development is planned.[104] Land-uses along the corridor run the gamut from pre-automotive commercial to big-box stores, from pre-automotive residential to single-family suburbs to recently built multi-family complexes, a transect generalizable to similar corridors.

[103] Reimagining 15-501, “Durham Chapel Hill Carrboro MPO, NC,” US 15 501 Corridor Study (Durham - Chapel Hill) | Durham Chapel Hill Carrboro MPO, NC, January 2020, https://www.dchcmpo.org/what-we-do/programs-plans/special-studies/us-15-501-corridor-study-durham-chapel-hill.

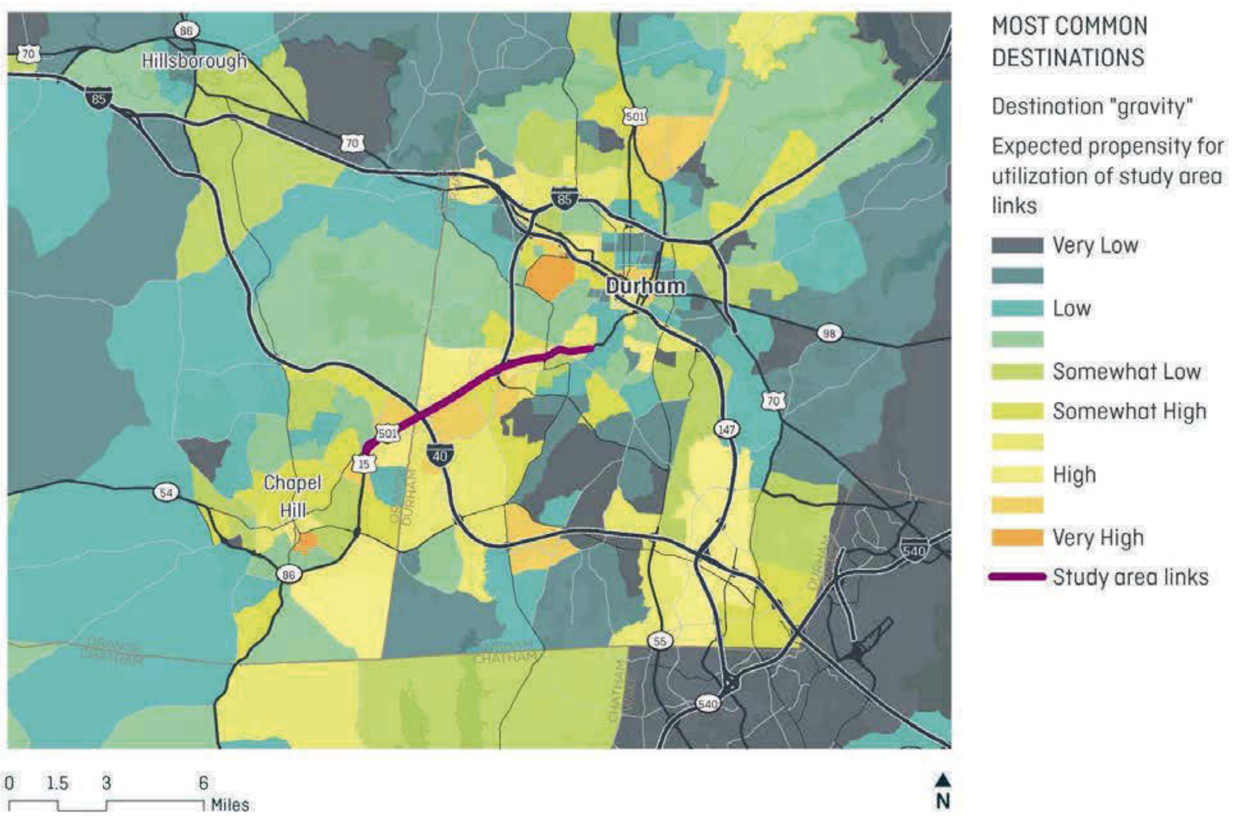
[104] DCHC MPO, “US 15-501 Corridor Study Report Summary,” January 2020, https://www.dchcmpo.org/home/showpublisheddocument/916/637489616311400000.

Corridor Impact Metrics

While analysis of the corridors provides a number of goals, each representative of each of the tensions described above, it fails to relate those goals to objectives or measures. Rather, it displays a naïve multimodal approach – providing additional facilities for each mode where space is available while failing to consider longer-term needs associated with network connectivity. For example, adding bicycle lanes expands the bicycle network, but the network remains fragmented, and no long-term plan for integration of the corridor within a broader network is presented. There is minimal consideration of the need to make long-term trade-offs between modes and to make preparatory actions to engage in activities such as securing right of way during bridge and structure widenings.

Measures used in the travel profile included the application of travel demand model-based data to identify origins and destinations along the corridor to identify the origin and destination of travel along the corridor, as shown in **Exhibit 54.**[105]

Exhibit 54 Destination Gravity



Another metric used to analyze travel behavior was a demographic comparison of the population within the corridor to the population within the metro area, as persons with different demographic characteristics have propensities to travel in different ways. The 15-501 study was novel in comparing not the population within

[105] DCHC MPO, "US 15-501 Corridor Study Report Summary," January 2020, https://www.dchcmpo.org/home/showpublisheddocument/916/637489616311400000.

the analysis zones next to the corridor, but in comparing the demographic characteristics of the population using the corridor, revealing the corridor was heavily used by a non-resident student population.

Takeaways

Travel model data can be used to analyze corridors in new and novel ways that traditional demographic analysis cannot, providing new insights into corridors users previously available only through survey purposes.

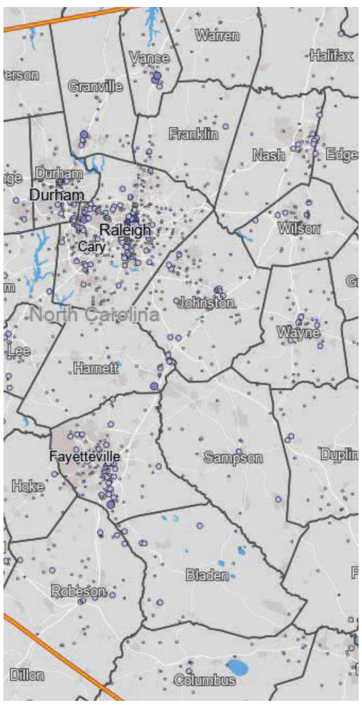
Despite their importance in multimodal transportation networks, most arterial corridors simply aren't managed in any multimodal sense. This is not an unexpected outcome, as it is difficult to manage a multimodal corridor due to the essential tension between the needs of each mode. Right of way is a scarce resource, and increasing it is always more or less costly, and grows more costly with time. Effective management of a multimodal system requires consideration of present and future right of way and effective actions to reserve portions of it for network capacity that that will be necessary in the future.

3.5.10 Corridor "Stop" #6: I-95 (North Carolina)

I-95 in eastern North Carolina provides a classic example of a "pass-through" corridor, which generates relatively little in-state economic activity while imposing significant preservation cost and is of vital national significance. I-95 is of interest as NCDOT has studied appropriate funding options for the corridor in an effort to consider its unique role.

I-95 crosses North Carolina north to south, from Virginia to South Carolina. The only major metro area/city along the route is Fayetteville MSA, with a 2019 population estimate of about 526 thousand. The corridor runs parallel to the Atlantic Coast railroad (the modern CSXT 'A' line), an active freight corridor as well as the route of several Amtrak Routes: Silver Meteor/Auto Train and (north of Selma) Carolinian and Piedmont. Intermodal connections to passenger rail exist at Rocky Mount, Wilson, Selma/Smithfield, and Fayetteville. There are no intermodal freight terminals, although one is planned for Rocky Mount in the near future. Transportation and warehousing employment in the corridor was concentrated in the southwest quadrant of Fayetteville as of 2017. The corridor is the primary freight route north-south across North Carolina.[106] It intersects with I-40 in Benson; I-40 is the primary East-West freight corridor from the port of Wilmington to points west. It connects to the CSX rail line to Wilmington in Wilson, and again in Lumberton (south of Fayetteville).

Exhibit 55
Population Density



The Fayetteville Metro is where a large number of state highways converge, including US-13 and US-401. It also has a partial beltway (I-295) and is where Norfolk-Southern and CSXT railroads meet. CSXT has a switching yard north of town. The corridor lies primarily in the coastal plain physiographic region and southeastern plains ecoregion, along the Atlantic Coast. Population density (2015) is shown below and is concentrated around Fayetteville.[107]

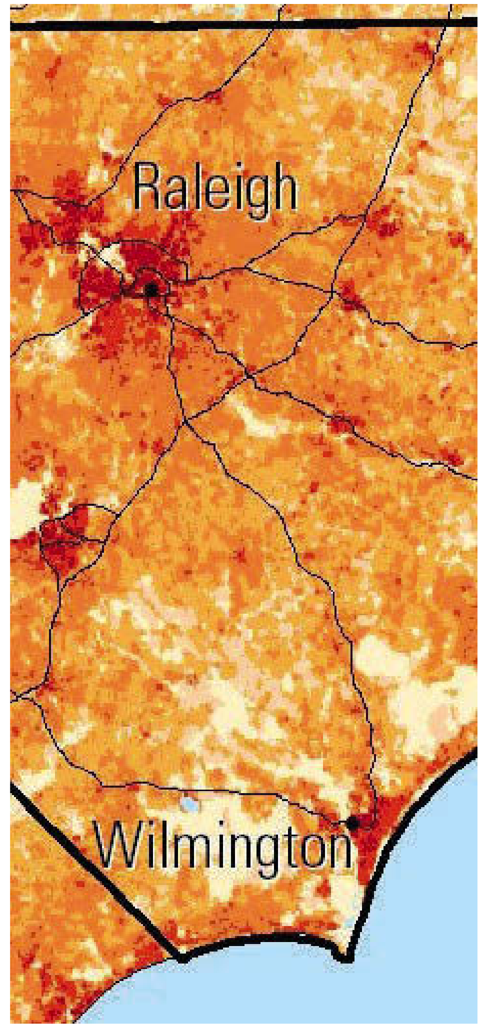
[106] Bureau of Transportation Statistics, "Freight Flows by Highway, Railroad, and Waterway: 2012," Freight Flows by Highway, Railroad, and Waterway: 2012 | Bureau of Transportation Statistics, accessed October 26, 2021, https://www.bts.gov/content/freight-flows-highway-railroad-and-waterway-2012.

[107] Adapted from: Cory Alden, "Exploring GPW Population and Modis Temperature Data in AppEEARS," LP DAAC - Exploring GPW Population and MODIS Temperature data in AppEEARS, August 7, 2017, https://lpdaac.usgs.gov/resources/data-action/exploring-gpw-population-and-modis-temperature-data-appeears/#2015-gpw-un-adjusted-population-density-dataset-over-north-carolina.

Zooming in on I-95

As mentioned, the I-95 corridor in North Carolina was selected for special consideration because it represents a corridor that is of more importance as a link to a national network than as a corridor within the state network. I-95 runs from Maine to Miami, FL, but Fayetteville is the only metro area it passes within North Carolina. Correspondingly, most of the traffic on I-95 in North Carolina is pass-through traffic, as the North Carolina segment forms a crucial link in the entire network. There are heavy truck segments on I-95; 23% of the traffic is truck traffic.[108]

Exhibit 56 **Major Roadways**



However, I-95 faces additional challenges: "I-95 in North Carolina was first built between 1956 and 1980, and with a few exceptions, it is basically the same four-lane highway today as when it was first built. Thus, it does not meet the most current interstate design standards."[109] Further, "this aging facility has geometric deficiencies, structural deficiencies, a higher than the statewide average fatal crash rate for interstates, and capacity deficiencies. Specifically, portions of this aging facility do not meet current roadway geometric requirements, including horizontal and vertical alignments, horizontal clearances, sight distances, interchange ramp designs, and interchange spacing."[110] Consequently, the corridor is less robustly engineered than similar facilities and is prone to flooding.[111] The corridor also has a maintenance deficit; 100% of pavement requires reconstruction, of which 15% needs immediate repair.[112] There is also a need for extensive replacement of existing structures (bridges and overpasses), both for the state of good repair and for roadway capacity needs. The cost of maintenance and improvements substantially exceeds the amount of funding available by state law.[113] Specifically, the 2013 "Strategic Prioritization Funding Plan for Transportation Investments" directs that:

> "no more than ten percent (10%) of the funds projected to be allocated to the Statewide Mobility category over any five-year period may be assigned to any

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[108] "Driving 95 Study: Documents for the Driving 95 Study," Driving 95 Study, accessed October 26, 2021, https://connect.ncdot.gov/projects/Pages/Driving-95.aspx.

[109] Cambridge Systematics, "North Carolina I-95 Economic Assessment Study ," June 2013.

[110] North Carolina DOT, "I-95 Planning and Finance Study: Financial Plan Update," January 2016, https://connect.ncdot.gov/projects/Driving95/I-95%20Financial%20Plan%20(Updated)%20.pdf.

[111] North Carolina DOT, "North Carolina USDOT BUILD Grant Application: I-95 Resiliency and Innovative Technology Improvements," July 2019, https://connect.ncdot.gov/resources/BUILD2019-I95/Documents/Narrative%20I-95%20Resiliency%20NCDOT.pdf.

[112] "Driving 95 Study: Documents for the Driving 95 Study," Driving 95 Study, accessed October 26, 2021, https://connect.ncdot.gov/projects/Pages/Driving-95.aspx.

[113] North Carolina DOT, "I-95 Planning and Finance Study: Financial Plan Update," January 2016, https://connect.ncdot.gov/projects/Driving95/I-95%20Financial%20Plan%20(Updated)%20.pdf.

> contiguous project or group of projects in the same corridor within a Highway Division or within adjoining Highway Divisions."[114]

Further, increasing the allocation of funding to the corridor is limited by the equity formula of the same law:

> "The equity formula, which requires that STIP funds be distributed equitably among regions of the State. STIP funds are distributed based on population (50 percent), on the number of miles of intrastate highways left to complete in a region (25 percent), and the remaining 25 percent is distributed equally among the regions."[115]

Using existing funding mechanisms, the combination of maintenance and improvements (4-lanes to 6 and 8-lanes) has been estimated to require 60 years to complete.[116] Alternative sources of funding (Federal, state, local) have been explored and dismissed. In North Carolina, the majority of highways are state-owned; county ownership is non-existent, and local roads are a small portion of total mileage. Hence the use of traditional local funds on the corridor is unsuitable.

Yet there exists a need to fund a corridor of national significance. Tolling has been explored as a potential solution capable of funding maintenance, road widening, and replacement structures. The state applied to participate in a special program to toll Interstate highways not fundable by other means called "Interstate System Reconstruction and Rehabilitation Pilot Program."[117] Yet tolling raises issues of equity – why toll only I-95, and why will only North Carolina residents along I-95 pay the additional cost of tolls? While some benefits accrue to proximate communities (tourism, etc.), substantial benefits are obtained by through traffic, at cost to the state host of the facility which exceeds the benefits of the facility. The state might also work with local agencies to reduce present/future demand on the facility through land-use and transportation planning efforts, thus making efforts to manage the demand generated by existing and future development would place on I-95. Matching additional capacity to present demand, and maintaining existing congestion levels, rather than adding capacity to meet forecast future demand would prevent induced demand from occurring.

Built to older standards, the corridor is also less reliable than comparable facilities. The roadways were not designed to handle more than a 100-year storm event, and Hurricanes and tropical storms have generated effects in excess of these limited design constraints. In addition to damaging roadway facilities, this forces vehicles to detour away from the Interstate, further inland, for substantial periods, thereby damaging network connectivity.

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[114] "§ 136-189.11. Transportation Investment ... - NCLEG.NET," accessed October 26, 2021, https://www.ncleg.net/EnactedLegislation/Statutes/PDF/BySection/Chapter_136/GS_136-189.11.pdf.

[115] North Carolina DOT, "I-95 Planning and Finance Study: Financial Plan Update," January 2016, https://connect.ncdot.gov/projects/Driving95/I-95%20Financial%20Plan%20(Updated)%20.pdf.

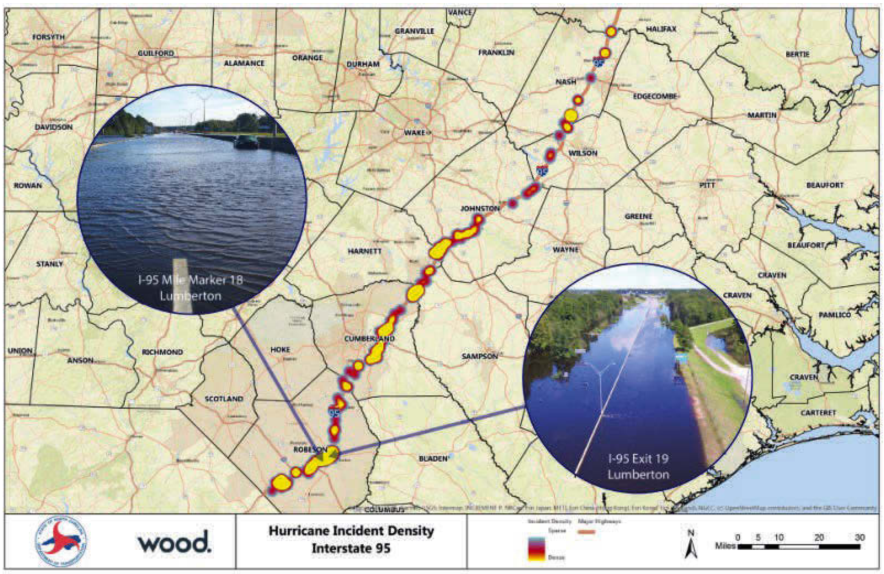
[116] "Driving 95 Study: Documents for the Driving 95 Study," Driving 95 Study, accessed October 26, 2021, https://connect.ncdot.gov/projects/Pages/Driving-95.aspx.

[117] "Federal Tolling Programs," FHWA, accessed October 26, 2021, https://www.fhwa.dot.gov/ipd/tolling_and_pricing/tolling_pricing/interstate_rr.aspx.

Corridor Impact Metrics

For the I-95 corridor in North Carolina, the 2016 BUILD grant lists safety, state of good repair, economic competitiveness and vehicular delay, reflecting the crash density; it also mentions the destructive effects of storm surge/flooding on the state of good repair, and maps (but does not quantify) recurrent flooding locations (shown in **Exhibit 57**).[118]

Exhibit 57 Hurricane Incident Density



However, the Benefit-Cost Analysis summary table for proposed projects in the corridor assigns almost all benefits to travel-time savings—not by reducing delay, but by reducing the need to deviate off the Interstate to a less direct, lower functional class road.

In contrast, the economic evaluation of the corridor focuses on the effects of traffic congestion on transportation costs and hence on economic competitiveness, noting the importance of tourism, and models the effects using a "customized economic model developed by Regional Economic Models, Inc."[119] Modeling required the development of a special travel demand model for the corridor, including likely diversion corridors, to be able to quantify effects. Travel demand models being somewhat 'black boxes', and rarely well documented, the outcomes of such analyses are not transparent. Outputs suggest that a 'Business as Usual' scenario with no capacity improvements would induce substantial financial welfare losses, a 'Build' scenario with no additional funding showing substantial congestion-induced delays, and two tolling scenarios—the outcomes were not substantially different. Notable in the use of performance measurement is the identification of 'Key Risks and Mitigation Strategies.'[120]

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[118] North Carolina DOT, "North Carolina USDOT BUILD Grant Application: I-95 Resiliency and Innovative Technology Improvements," July 2019, https://connect.ncdot.gov/resources/BUILD2019-I95/Documents/Narrative%20I-95%20Resiliency%20NCDOT.pdf.

[119] Cambridge Systematics, "North Carolina I-95 Economic Assessment Study ," June 2013.

[120] North Carolina DOT, "I-95 Planning and Finance Study: Financial Plan Update," January 2016, https://connect.ncdot.gov/projects/Driving95/I-95%20Financial%20Plan%20(Updated)%20.pdf.

Exhibit 58 **Key Risks and Mitigation Strategies**

Risk Category	Description	Mitigation
Schedule	Ability to secure all required approvals and permits	NCDOT has initiated NEPA review process
	Scheduling and coordination - critical in meeting milestones and deadlines	NCDOT will actively monitor and update schedule
Cost	Construction costs may escalate as contracts execute	NCDOT will review their potential to affect cost. Estimates include contingencies to address unknowns.
	Phase 1 cost overruns	Cost will be closely monitored
	Higher than assumed inflation rate could result in cost increases and delays	Recent construction inflation trends used. Reserves to compensate for higher inflation.
	O&M and R&R cost increases could lower revenue available to repay debt	Higher than existing level of maintenance is assumed
Financing and Revenue	Access to capital can be difficult for start-up toll projects	Matching demand for bonds for tolling projects with supply has not been an issue. Multiple debt issuances will ease risk concerns.
	If interest rates are higher than assumed, more toll revenues will be needed to repay debt	There is enough contingency built in the financial model to address interest rate increases
	Toll revenues could be lower than expected	Financing is based on reasonable forecasts
	Issues with toll equipment could affect payments' collection	Assumed 5% lost revenue

The example of I-95 in North Carolina has several important lessons to impart regarding corridor management. Primarily, it raises the question of how to fund a corridor of national importance that is not a corridor of state DOT importance. The Federal government can only indirectly mandate gas-tax priorities within states to target corridors of national importance. Given a prior history of minimal investment, and an explicit policy limiting the spending by the corridor, a sudden change in state spending priorities seems unlikely to benefit I-95. The 2016 BUILD grant suggests the way forward-- projects on the I-95 corridor in North Carolina will be funded on an ad-hoc basis through grants and loan funds like TIGER/BUILD, ARRA and TIFIA—beauty pageants judge by Federal metrics, rather than state spending priorities.

In a performance measures context, the evaluation of corridor characteristics fails in an important way: it fails to establish targets regarding what constitutes acceptable levels or trends in the performance measures. Goals and objectives are established explicitly, and metrics implicitly, but no targets for metrics are set, making it impossible to determine sufficiency or preference investment in achieving one goal over another. Minimally, to preserve the link, the network structures will need to be rebuilt; failure to add capacity during rebuilding (thus creating a future choke point) would be a severely sub-optimal strategy. Given that funding for the corridor almost certainly be substantially less than necessary to meet corridor goals, some method of making trade-offs between goals to determine funding effectiveness is necessary—to evaluate the benefits of investments in state of good repair or safety against investments in resilience or additional peak-hour capacity. Given the age of the corridor in question and the bridges/ structures on the corridor, the issue is a pressing one.

3.5.11 Corridor "Stop" #7: Atlanta, GA

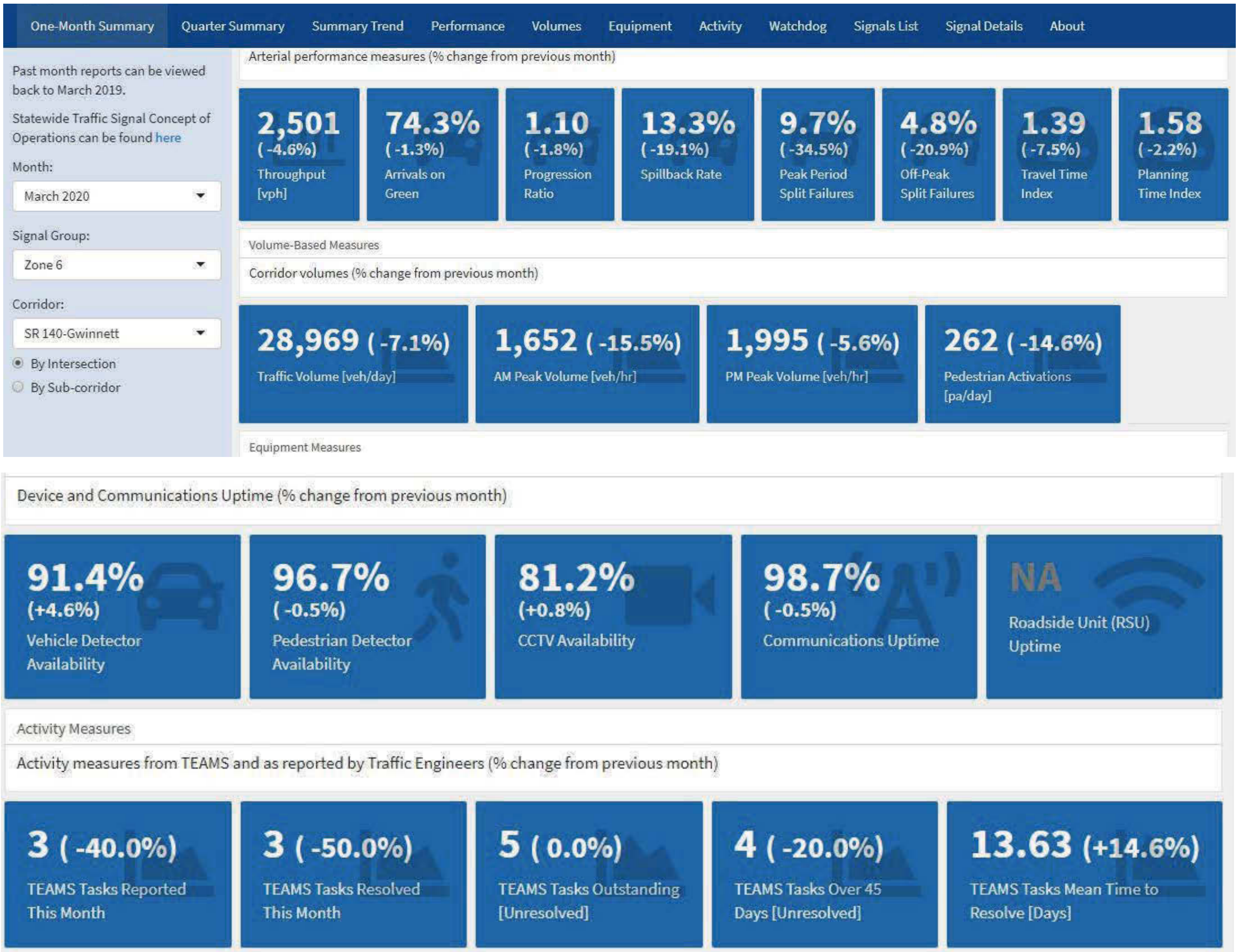
Atlanta is among the most rapidly growing and performance-challenged locations in the I-95/Eastern Seaboard corridor system. Three areas are worth discussing on this stop: 1) corridor performance measures and public-facing dashboards, 2) freight and 3) planning and environmental linkage (PEL). More information regarding corridor management strategies in metro Atlanta can be found further down in the *Other Considerations* section of this report.

Corridor Performance Measures

The Georgia Department of Transportation (GDOT) has been managing corridors through a Regional Traffic Operation Program (RTOP) for the last 10 years and has been measuring performance since then. It has been within the last two years that GDOT has outfitted its signals (and local jurisdiction signals) with new technology that allows them to report more data with an interactive dashboard using Automated Traffic Signal Performance Measures (ATSPM) and other data, such as National Performance Management Research Data Set (NPMRDS). Based on this case study, GDOT is leading the nation in performance reporting through RTOP and how they message and monitor this information for quick response to maintenance and operational needs. Based on an interview with GDOT, each corridor has its unique operation needs where some focus on throughput, while others focus on multimodal and pedestrian safety. The traffic signal data can report out on these, along with dozens of other metrics. Error! Reference source not found. illustrates one corridor's dashboard as part of GDOT's Measurement, Accuracy, and Reliability Kit (MARK 1).

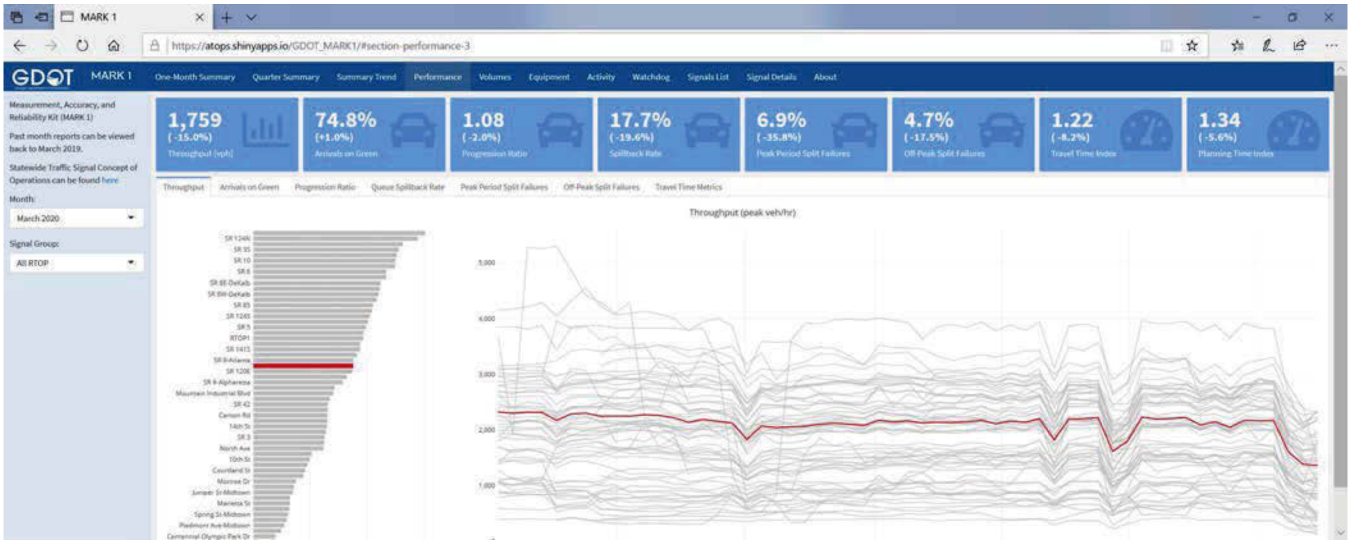
The dashboard provides detail on each of the measures to demonstrate trends over one month to multiple

Exhibit 59 GDOT RTOP Corridor MARK 1 Performance Dashboard[1]



years. GDOT uses this information to work with local jurisdictions to adjust operations of a corridor to meet thresholds set specifically for the corridor. GDOT recently added a new performance measure, which is to monitor roadside units (RS U) as a part of the connective vehicle program. **Exhibit 60** illustrates another example of how the data are displayed with easy-to-understand charts.

Exhibit 60 **GDOT RTOP Corridor MARK 1 Performance Dashboard Vehicle Throughput Example**[121]



It should be noted that these performance measures are implemented across the state in both urban and rural areas. In areas outside of metro Atlanta, the program is referred to as Regional Traffic Operations Program (RTSO). This integration is a newer initiative and GDOT is continuing to add to the dashboard. It should also be noted that a similar dashboard is available with a password to monitor data for interstates. However, this is much more simplified because the movements on the Interstate are less complex than on arterial roadways with traffic signals. This dashboard uses data received through the 511 systems on the interstates and a program called Instadata.

Freight Management

The movement of goods is vital to the economic welfare of not only metro Atlanta but also the State of Georgia. The state is in the process of expanding the Savannah Port, making it one of the largest ports on the Eastern Seaboard. State leadership anticipates this will result in increased truck traffic on interstates and highways. To prepare for this surge in freight, the state and regional leaders are taking action.

GDOT is in the Plan Development Process (PDP) for new, dedicated commercial vehicle lanes along I-75 between Macon, GA, and Atlanta, GA. According to the project fact sheet, "the I-75 Commercial Vehicle Lanes Project will improve mobility and safety for freight operators and passenger vehicles. The project consists of two barriers that separated commercial vehicle-only lanes along I-75 from approximately the I-475/I-75 Interchange near Macon to the McDonough area. The project will benefit all motorists by reducing congestion and improving safety while offering direct economic benefits to travelers in Georgia as well as freight and logistic carriers in the Southeast."[122] These will be the first new and fully dedicated lanes for commercial vehicles in the US.

[121] "Georgia DOT SigOps Metrics," SigOps Metrics, accessed October 26, 2021, http://sigopsmetrics.com/main/.

[122] Georgia DOT, "I-75 Commercial Vehicle Lanes - Cdn.majormobilityga.com," February 11, 2020, https://cdn.majormobilityga.com/wp-content/uploads/2020/02/19135502/I-75-CV-Lanes-Fact-Sheet-_10.pdf.

I-75 Commercial Vehicle Lanes[123]

Exhibit 61 I-75 Commercial Vehicle Lanes

In an interview with GDOT, they stated that nearly 90% of northbound truck traffic on I-75 between I-475 in Macon to the end of the project corridor travel the full length of the corridor. This is going to result in fewer required access points in and out of the dedicated lanes, which could increase throughput for both trucks and passenger vehicles and increase safety by reducing conflict points. GDOT will continue to collect operation and performance data for the Interstate and will be able to present before and after performance results of the project.

GDOT is also conducting a statewide truck parking analysis to understand how the state can better manage and provide truck parking. This study is unique in that it is coordinating with neighboring states to understand parking availability just across the state lines and to have a cohesive approach to parking, which is vital to the economy. On a more regional scale, the Atlanta Regional Commission recently wrapped up a truck parking study for metro Atlanta identifying key locations where parking is needed based on freight movements. ARC is also conducting several "freight cluster plans" focusing on improvements in areas where freight is prevalent as an attempt to more efficiently move goods through and around Atlanta, but also to look at strategies to reduce conflicts between freight trucks and passenger vehicles, especially in areas where industrial and residential land-uses are adjacent to one another.

Planning Environmental Linkage (PEL)

Planning and Environmental Linkages (PEL) is an emerging movement in transportation planning - coordinating planning and environmental efforts much earlier in the process. It allows governments to append planning documents, such as an alternatives analysis to the NEPA document, which reduces duplication. The Federal Highway Administration (FHWA) identified PEL as one of the ten initiatives for states to use to expedite the transportation planning and environmental process.[124] Georgia is using this tool to advance corridor projects, including I-85. According to the project website, "the study is utilizing FHWA's Planning and Environmental Linkages (PEL) framework to encourage transportation decision-makers to incorporate environmental considerations, community, and economic goals early in the transportation planning process. Decision-makers can then rely on more robust planning analysis, studies, and decisions throughout project development and during the environmental review processes of transportation projects. PEL aims to create a more unified decision-making process, resulting in less duplication of efforts and more informed project-level decisions."[125] Exhibit 62 illustrates the project study area.

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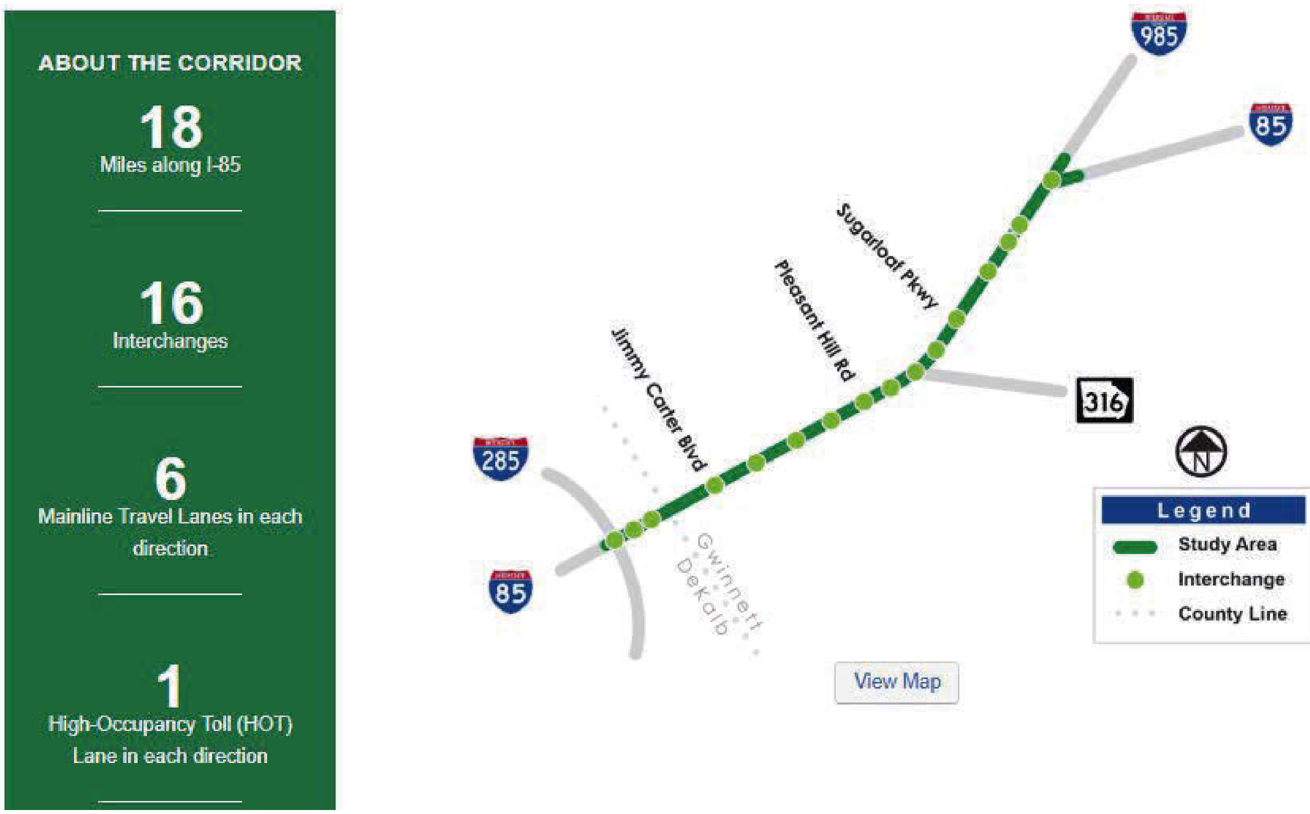
123 Georgia DOT, "I-75 Commercial Vehicle Lanes - Cdn.majormobilityga.com," February 11, 2020, https://cdn.majormobilityga.com/wp-content/uploads/2020/02/19135502/I-75-CV-Lanes-Fact-Sheet-_10.pdf.

124 "Planning and Environmental Linkages," U.S. Department of Transportation/Federal Highway Administration, November 18, 2016, https://www.fhwa.dot.gov/innovation/everydaycounts/edc-1/PEL.cfm.

125 "85 Study Planning & Environmental Linkages (PEL)," 85 Study, accessed October 26, 2021, https://85study-gdot.hub.arcgis.com/.

During an interview with GDOT, it was stated that as the first PEL study for the Department, implementing the PEL framework along the I-85 corridor has resulted in not only increasing collaboration between the offices of planning and environmental, including cross-training opportunities, but it has also resulted in the development of a task force. The purpose of the task force is to develop a PEL guidebook for GDOT, including determining when it is appropriate to implement PEL on different scaled corridor studies and how.

Exhibit 62 Corridor Study Area[126]



126 "85 Study Planning & Environmental Linkages (PEL)," 85 Study, accessed October 26, 2021, https://85study-gdot.hub.arcgis.com/.

Atlanta's Livable Centers Initiative (LCI Program)

The Atlanta Regional Commission's (ARC) Livable Centers Initiative (LCI) program awards grants to local jurisdictions and Community Improvement Districts (CIDs) to develop plans that "re-envision their communities as vibrant, walkable places that offer increased mobility options, encourage healthy lifestyles and provide improved access to jobs and services."[127] LCI study areas can be activity centers or corridors of varying sizes and characters within the metro Atlanta region. The program has existed since 2000, focusing on combining land-use and transportation improvements to create vibrant, livable places.

Exhibit 63 LCI Program Objectives

Source: Atlanta Regional Commission)

The LCI Program Goals are to:

- *Encourage a diversity of housing, employment, commercial, shopping and recreation land-uses at the transit station, local and regional center level accessible by people of all ages, abilities and income levels;*
- *Enhance access to a range of travel modes including transit, roadways, walking and biking and increase roadway connectivity to provide optimal access to all uses within the study area; and,*
- *Foster public-private partnerships and sustained community support through an outreach process that promotes the involvement of all stakeholders, including those historically underserved or underrepresented.*

Non-traditional corridor impact objectives include: Housing affordability, increased green infrastructure, workforce development, historic preservation, access to healthy food, lifelong communities, creative placemaking, and smart communities. As the positive impact of actions taken to promote these corridor management objectives can only be measured by looking back after many years, there isn't anything to "manage" frequently. The objective is to change policies and build infrastructure based on ex-ante anticipated results, then look backward at select points to see how well the desired results actually happened.

In addition to planning grants, the ARC also sets aside a portion of funds in the MPO's Regional Transportation Plan for the implementation of projects recommended in LCI plans. LCI grant recipients must submit status update reports every five years describing LCI plan projects completed and underway, as well as other outcomes of the plans, such as rezoning that occurred as recommended by the plans. Every 10-15 years, the plans are eligible for funding of major plan updates. The ARC periodically issues reports on the LCI program's overall impact in the region, including metrics of the studies themselves and resulting transportation projects, as well as a summary of new development, parks, and public art within LCI areas compared to the region.

[127] "Livable Centers Initiative," ARC, September 3, 2021, https://atlantaregional.org/community-development/livable-centers-initiative.

Atlanta Takeaways

Limitations of Inter-Regional Impact Measures & Lack of Over-Arching Framework:

Overall, observations in the I-95/Eastern Seaboard system show that indicators are either regional or are statewide and the coalition is not actively utilizing any multistate indicators much less a framework for organizing impact measures. This results in varying metrics to measure performance. Further, none of the agencies researched for this case study appear to report on system resilience indicators. Finally, economic impacts are not widely used as a measure and when they are, there are discrepancies on how ROI is measured with no consistent metrics for benefits and costs.

What is found, however, is that all case study areas recently updated or are currently updating their performance measures. It is also notable the scale at which scale data are being collected and evaluated. For example, GDOT is re-vamping its statewide performance measure dashboard to include the federally required measures, as well as new measures. VDOT focuses its performance measures on a corridor-by-corridor basis, considering the unique characteristics of the corridor segments since many of their corridors traverse both urban and rural areas. Boston is focusing its performance measures on a project-by-project basis, evaluating performance before and after implementing a capacity or operational improvement. Notably, performance is defined in different ways for each region as well, ranging from operational and capacity performance to incident and event management, as described at each corridor "stop" above.

Through the Eastern Seaboard case study, there are several corridor management challenges and strategies that affect both metropolitan and non-metropolitan areas. Below are some additional considerations when developing a corridor strategy.

Conflicting Land-Uses

As metropolitan areas continue to grow and the e-commerce economy trends upward, the need for efficient goods and freight movement also continues to increase. This is putting a strain on conflicting land-uses, particularly those communities where distribution and warehousing facilities are near residential areas. This is a trend that is affecting many metropolitan areas. Numerous measures are being taken to minimize these conflicts.

The Southern Fulton Comprehensive Transportation Plan (CTP), currently underway by the Atlanta Regional Commission (ARC), has developed a corridor framework to assist with addressing some of these transportation and land-use conflicts.[128] As part of the corridor framework, a system-wide smart corridor network was identified, with certain corridors focusing on transportation improvements to improve the movement of freight and goods while others included mobility options to provide more livable corridors. For example, trucks may be incentivized to use designated smart freight corridors where additional green time would be given to trucks during off-peak hours (freight signal priority).

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[128] Atlanta Regional Commission and Modern Mobility Partners, "Southern Fulton Comprehensive Transportation Plan ," Southern Fulton Comprehensive Transportation Plan Update Home, August 2020, https://www.southernfultonctp.org/.

Other studies in the area are also looking to address concerns, such as ARC's Aerotropolis Freight Cluster Plan and a Regional Land-use study (a multi-city effort) to evaluate and compare land-use and zoning codes for a more consistent land-use/zoning plan.[129]

Truck Parking

Truck parking was discussed in the Atlanta "stop," however truck parking is also a national challenge, especially with the recent legislation for truck drivers to keep electronic logs and strict restrictions on drive time limits. This is resulting in illegally parked trucks in both urban and rural areas, along interstates, on private property, and even sometimes local roads. FHWA has created a National Freight Parking Coalition to tackle these challenges from a national level.[130] However, states are also looking at solutions. GDOT is currently underway with a statewide truck parking analysis, identifying all available parking locations, both authorized and unauthorized, and coordinating with neighboring states to develop a comprehensive plan to help meet the truck parking demand in Georgia. VDOT is also managing truck parking by adding capacity at parking facilities and integrating parking availability notifications to drivers.[131] They are currently underway in updating their notification system to provide more accurate availability information. Truck parking is also one of the I-95 Corridor Coalition's top priorities, assisting the Eastern Seaboard states with truck parking initiatives.[132]

Connected and Autonomous Vehicles

As technology continues to develop, connected and autonomous vehicles (CAV) continue to gain attention at the national and state level. Interviews with DOTs and MPOs confirmed this is a challenge for most, primarily because the future is not yet known. At the federal level, there is debate over what spectrum should be reserved for CAVs and currently some of, what they refer to as the "safety spectrum" has been released for wireless internet usage.[133] However, states and MPOs are continuing to monitor and some states are moving their infrastructure to accommodate CAVs.

In Georgia, GDOT is in partnership with ARC to implement a new program called CV1K+ (Connected Vehicle 1,000+). This project intends to outfit every traffic signal with dedicated short-range communication (DSRC) and cellular communication specifically for CAVs. The first round of 1,000 signals is currently underway with estimated completion in 2022. GDOT and ARC will continue this partnership until all 5,000 (plus or minus) signals have the CAV capabilities.

As a part of this program, GDOT and ARC are asking the vendor to also provide signal pre-emption and signal priority capabilities. Signal pre-emption refers to when a vehicle with a transponder has the necessary permissions to receive all green lights as they approach traffic signals. This is primarily used for emergency first responders. Signal priority gives vehicles extended green lights or may reduce red-light time to keep the vehicle moving with reduced delay. This is typically used for transit vehicles to keep on schedule. However, there is recent interest to create a signal priority program for commercial vehicles to keep freight and goods

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[129] Gresham Smith, Modern Mobility Partners, and PEQ, "Freight Cluster Plan," ATL Airport Community Improvement Districts, November 2020, https://aerocids.com/project/study-freight-cluster-plan/; "Special Projects," Aerotropolis Atlanta, November 18, 2020, https://aeroatl.org/special-projects/.

[130] "Truck Parking," Truck Parking - FHWA Freight Management and Operations, accessed October 26, 2021, https://ops.fhwa.dot.gov/freight/infrastructure/truck_parking/.

[131] "VDOT Virginia Traffic Information," Virginia 511 Web, accessed October 26, 2021, https://www.511virginia.org/.

[132] "Truck Parking," The Eastern Transportation Coalition, October 5, 2020, https://tetcoalition.org/projects/truck-parking/.

[133] "The Safety Band #Safetyband," U.S. Department of Transportation, accessed October 26, 2021, https://www.transportation.gov/content/safety-band.

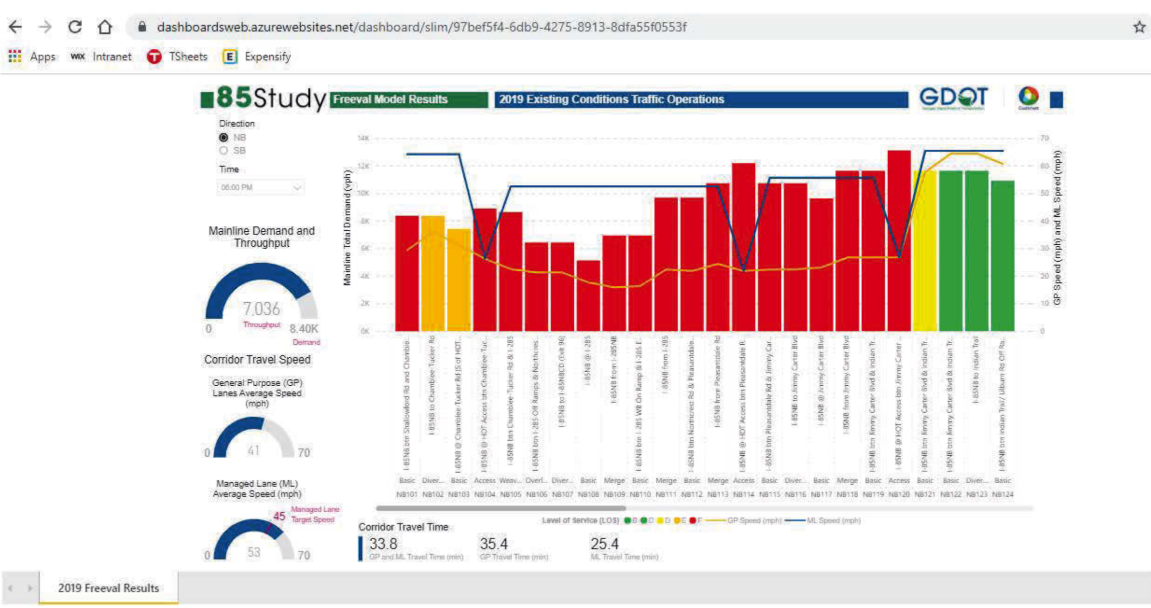
flowing with reduced delay but may also be a strategy to incentivize distribution and warehouse facilities to schedule pick-ups and drop-offs during off-peak hours help reduce conflicts between trucks and passenger vehicles (i.e., freight signal priority).

Through the review and interviews, another trend emerged. Many smaller MPOs are not considered for testing beds because they do not have the population and employment desirable for many manufacturers. However, PlanRVA indicated that they believe their MPO, as well as others similar in size, would be a great opportunity for testing because they do not have the congestion of larger MPOs.

Performance Measure Dashboards

Some performance measure dashboards were discussed in the “stops” and provided good examples of what states and MPOs can do to help display performance measure information. However, in many cases, there are challenges associated with maintaining dashboards, especially at the corridor level. Both GDOT and VDOT take advantage of NPMRDS and other data sources to feed their system-wide performance measures, but dashboards for corridors are established for a particular purpose, such as a study and remain static. GDOT has implemented dashboards for its arterial corridors using traffic signal ATSPM data, but the public may not be aware of its existence. Richmond also takes advantage of VDOT data and other free data to develop story maps to display corridor performance information, but this information is static and must manually be updated. One example of a corridor dashboard platform that may be helpful is the GDOT I-85 Study currently underway in metro Atlanta. **Exhibit 64** shows an example of this dashboard that is currently under development.

Exhibit 64 I-85 Dashboard[134]



134 “Freeval Model Results/ 2019 Existing Conditions Traffic Operations,” 85 Study, accessed October 26, 2021, https://dashboardsweb.azurewebsites.net/dashboard/slim/97bef5f4-6db9-4275-8913-8dfa55f0553f.

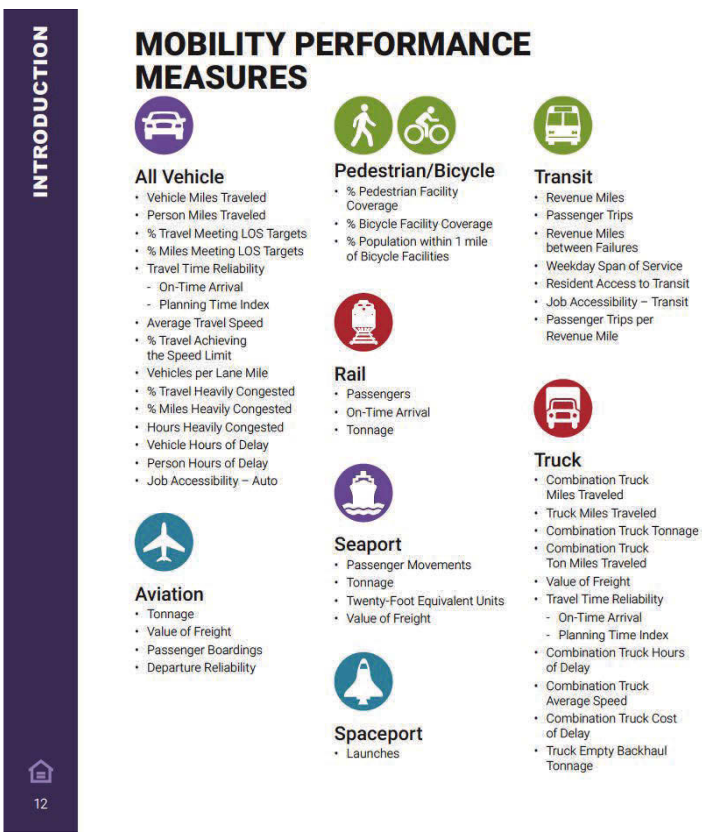
3.5.12 Corridor Stop #8: South East Florida

FDOT Department of Transportation – District 4 has one of the most comprehensive multimodal perspectives on the corridor system of any jurisdiction in the I-95/Eastern Seaboard corridor system. Multimodal Mobility Performance Measures (MMPM) help bring people together to understand and discuss how all the different plans can work together by sharing the same measures in each plan and jurisdiction within the district.

The Florida DOT Central Office has developed a rich set of performance measures that define mobility for every mode, either moving people or freight, using four dimensions (quantity, quality, accessibility, and utilization). In 2019, the measures included in the FDOT Source Book are shown in **Exhibit** 67.

These measures have been used in dashboards and reports (Exhibit 67) specifically for I-95.

Exhibit 65 **Multimodal Mobility Performance Measures**



INTRODUCTION

MOBILITY PERFORMANCE MEASURES

All Vehicle
- Vehicle Miles Traveled
- Person Miles Traveled
- % Travel Meeting LOS Targets
- % Miles Meeting LOS Targets
- Travel Time Reliability
  - On-Time Arrival
  - Planning Time Index
- Average Travel Speed
- % Travel Achieving the Speed Limit
- Vehicles per Lane Mile
- % Travel Heavily Congested
- % Miles Heavily Congested
- Hours Heavily Congested
- Vehicle Hours of Delay
- Person Hours of Delay
- Job Accessibility – Auto

Aviation
- Tonnage
- Value of Freight
- Passenger Boardings
- Departure Reliability

Pedestrian/Bicycle
- % Pedestrian Facility Coverage
- % Bicycle Facility Coverage
- % Population within 1 mile of Bicycle Facilities

Rail
- Passengers
- On-Time Arrival
- Tonnage

Seaport
- Passenger Movements
- Tonnage
- Twenty-Foot Equivalent Units
- Value of Freight

Spaceport
- Launches

Transit
- Revenue Miles
- Passenger Trips
- Revenue Miles between Failures
- Weekday Span of Service
- Resident Access to Transit
- Job Accessibility – Transit
- Passenger Trips per Revenue Mile

Truck
- Combination Truck Miles Traveled
- Truck Miles Traveled
- Combination Truck Tonnage
- Combination Truck Ton Miles Traveled
- Value of Freight
- Travel Time Reliability
  - On-Time Arrival
  - Planning Time Index
- Combination Truck Hours of Delay
- Combination Truck Average Speed
- Combination Truck Cost of Delay
- Truck Empty Backhaul Tonnage

12

Exhibit 66 Southeast Florida Partners

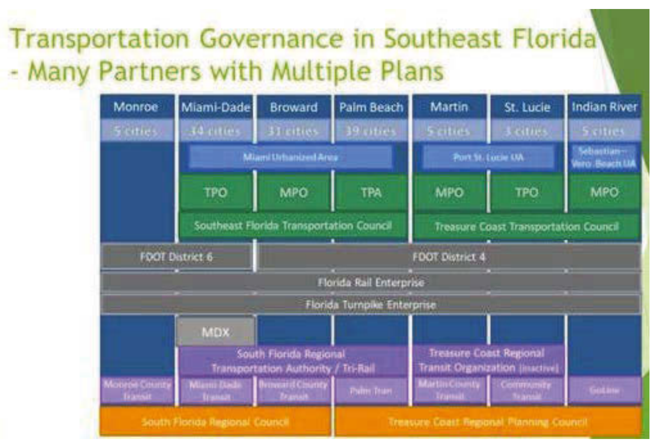
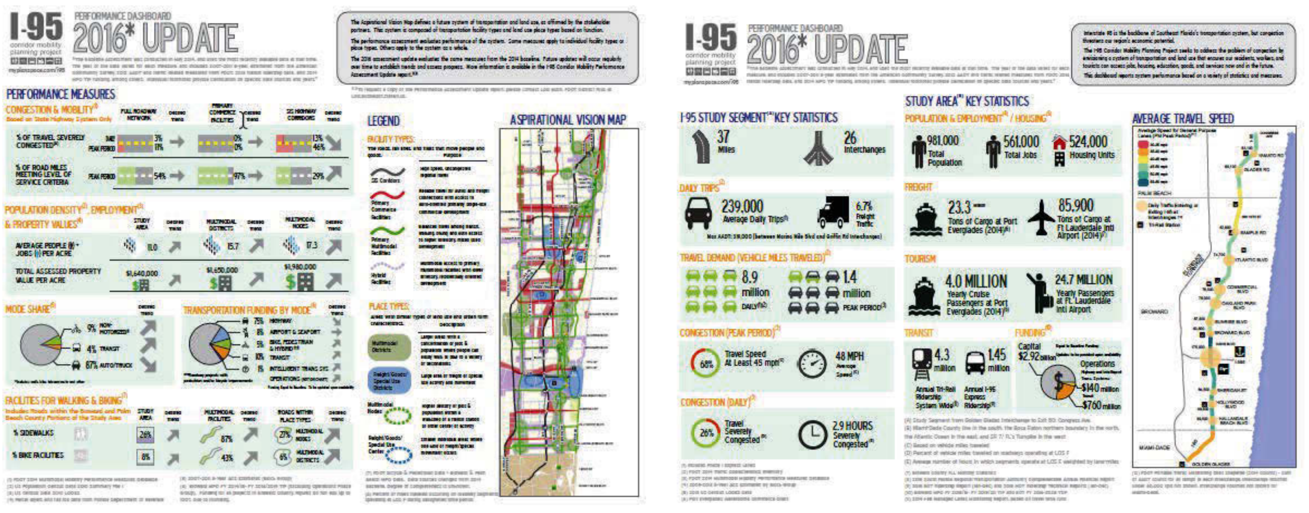


Exhibit 67 **I-95 Performance Measure Dashboard**



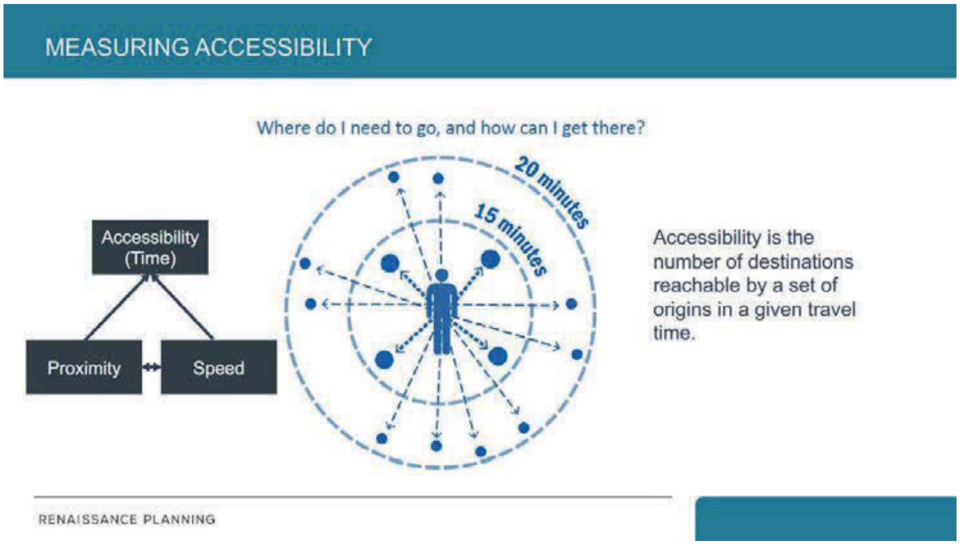
This common set of measures is used by a number of different transportation and land-use plans in the D4 region of the cities surrounding West Palm Beach. It required many hours of discussion for the range of stakeholders to understand the measures. Travel time reliability is an excellent mobility measure but not easily understood. Making the connection between land-use and planning is not an easy task, but the multimodal mobility performance measures provided a common framework of data that was incorporated into both the land-use and transportation plans for the region. One of the most significant benefits is that the land-use and transportation plans are now using the same data from the same source to measure the impacts on the system from the implemented strategies and completed projects. The outcomes are measured using the same criteria. This common denominator should help improve the entire system that surrounds I-95. If local trips don't use the interstate facility, then it serves the entire region better.

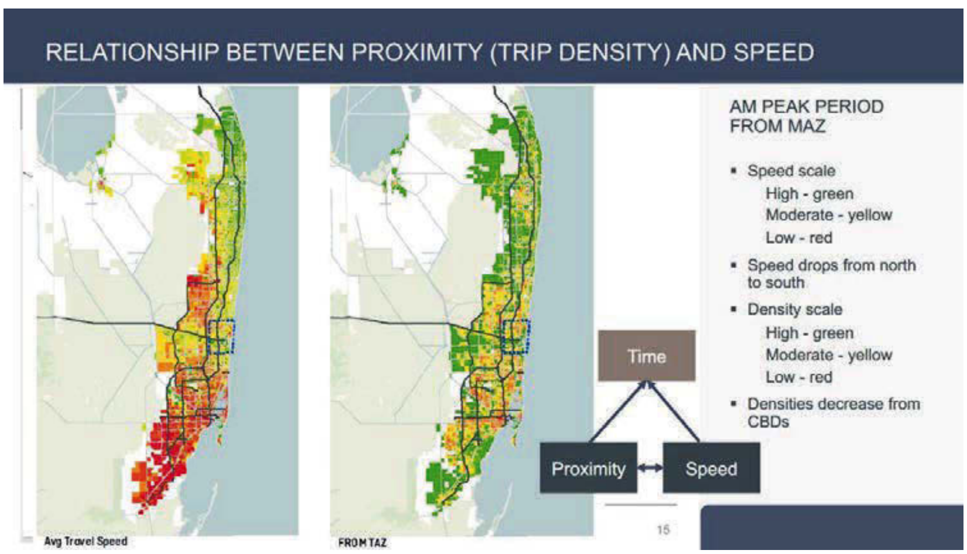
What's in the future:

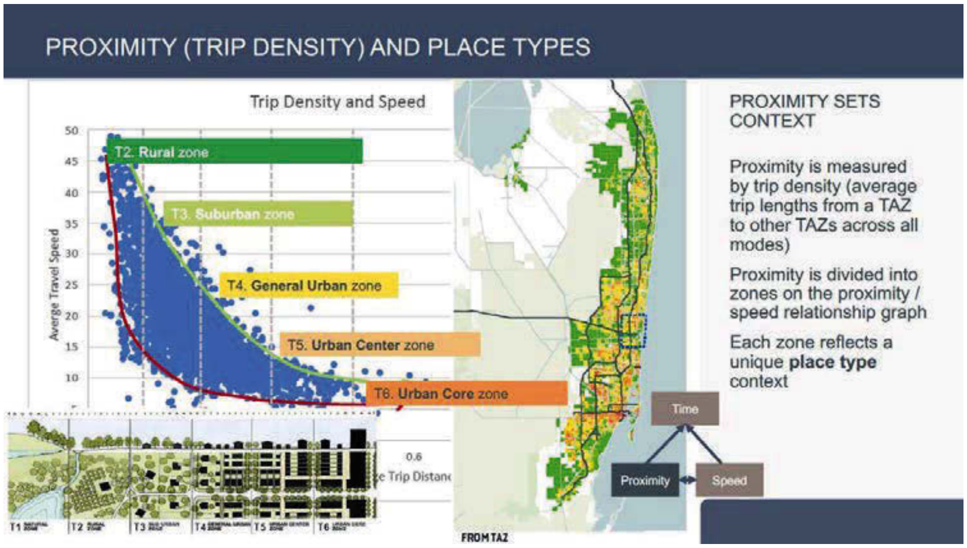
The district and its partners have developed a new "Core Measure" for accessibility, the Multimodal System Productivity (MSP). Accessibility is the number of destinations reachable by a set of origins in a given travel time as shown in Exhibit 68. This single measure is mode-independent. It doesn't matter if you walk, bike, take transit or drive. It measures how many trips can be made on the network. The MSP measure shows trip density. One very interesting metric that arises from the data is that most trips are about 20 minutes. This then provides a useful comparison measure. How many complete trips are made within 20 minutes, regardless of mode? The data shows that even where speeds are very low in the congested downtown of Palm Beach, the number of trips that are completed is very high because many are made by either foot or very short commutes.

Data is a challenge, but by using current technology to gather the Origin Destination of all trips regardless of mode, it shows that the average trip is 20 minutes. This measure provides the Land-use/Mobility connection that shows well-developed urban centers can accommodate many more trips than any auto-oriented road.

Exhibit 68 **Multimodal System Productivity (MSP)**







3.5.13 Eastern Seaboard/I-95 & I-85 System Takeaways

Major takeaways from the Eastern Seaboard case study include several ways to measure performance within a corridor ranging from operational performance, incident management, commercial vehicles and connected and autonomous vehicles. While each state and/or MPO may measure their corridors differently, they are following federal guidelines and identifying additional measures to meet the needs of their area. Overall, there are some opportunities to coordinate on performance measures which could open an opportunity for states to discuss how to disseminate

Exhibit 69 I-85/I-95 Eastern Seaboard SWOT

Topic	SWOT			
	Strengths	Weaknesses	Opportunities	Challenges
Truck parking	GDOT is conducting a statewide truck parking study and partnering with neighbor states to understand parking capacity on the other side of the border. VDOT is managing truck parking by adding capacity at parking facilities and integrating parking availability notifications to drivers. Truck parking is also one of the I-95 Corridor Coalition's top priorities, assisting the Eastern Seaboard states with truck parking initiatives.	Lack of available truck parking is a current challenge in many locations and nation-wide.	Opportunities exist to measure truck parking availability and provide solutions through new spaces, partnerships, and technologies.	Truck parking will likely continue to be a challenge as freight volumes increase with e-commerce.

Commercial Vehicle Lanes	GDOT is implementing new dedicated commercial vehicle lanes to improve freight performance on I-75 south of Atlanta.	High cost of implementation for new dedicated lanes.	Opportunities exist for expansion of dedicated commercial vehicle lanes.	Availability of funding for mega projects.
Planning & Environmental Linkage (PEL)	GDOT is starting to include PEL in studies, such as the I-85 Corridor Study.	Many transportation agencies are not familiar with PEL and its benefits.	Opportunities exist to incorporate PEL into more planning and environmental studies to streamline project delivery.	Limited funding and increased cost of PEL early on in corridor studies.
	Strengths	**Weaknesses**	**Opportunities**	**Challenges**
Corridor Planning & Funding	Richmond MPO conducts Corridor Studies and the state is considering legislation for funding for improvements specific to corridors.		Opportunities exist to identify dedicated funding for corridor planning, monitoring, and implementation.	Reduced motor fuel tax revenue due to COVID-19, as well as increased market penetration of electric vehicles.
Public-Facing Open Data & Dashboards	Many DOTs and MPOs use public data dashboards. Interactive dashboards are becoming increasingly common (e.g., PlanRVA, VDOT, GDOT, I-85, MassDOT, and Boston MPO dashboards).	In many cases, data is static and becomes out of date. Smaller MPOs like Richmond noted limited capacity and funding to collect their own data.	Opportunities to update data more frequently or use data feeds for automatic updates. Data sharing partnerships reduce cost burden.	Inconsistent data sources lead to different measurements and analytic methods used.
Corridor Management - Hazardous Incidents (Hurricanes, Snowstorms, etc.)	The I-95 Corridor Coalition facilitates coordination among the states and jurisdictions along the entire corridor. VDOT is a leader in incident management, using real-time data collection and response. Many forms of ICM are being used - Ramp Metering, Variable Message Signs (VMS), Traveler Information, Active Traffic Management (Speed harmonization, lane control, queue warning),	Technology and needs along the corridor vary by state.	Increased collaboration between jurisdictions to leverage current and planned technologies and programs.	As states adopt new approaches to corridor management, lack of coordination could lead to a disjointed system.

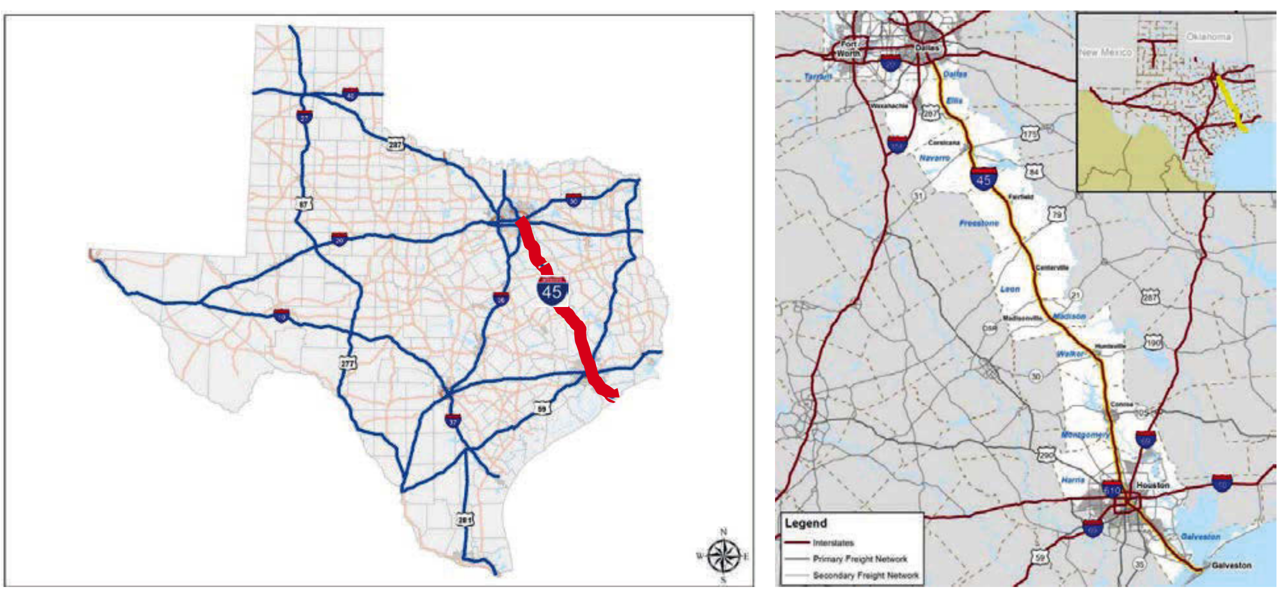
	Incident Management, Road Weather Management, Traffic Actuated Signals, VII Enabled, Detection Algorithm, Surveillance Cameras, On-Call Patrols, 511.			
	Strengths	**Weaknesses**	**Opportunities**	**Challenges**
Connected Vehicles (CV) / Integrated Corridor Management (ITS)	GDOT/ARC have begun installing communication infrastructure for CAVs (including CV1K+ program). ARC has identified a smart corridor network as part of the Southern Fulton Comprehensive Transportation Plan.	Many areas across the country have been developing smart corridors as one-off studies or projects and not as part of a strategically identified smart corridor network or system.	Opportunities exist to expand CV readiness by installing communication infrastructure and implementing pilot programs. Proactive development of regional smart corridor networks. Smaller metro areas may be good testing grounds for AVs due to lower traffic volumes.	Uncertainty regarding technology presents challenges.
Performance Measures	GDOT's RTOP and RTSO programs actively manage key corridors in the state and use performance reporting to monitor and respond quickly. The Boston MPO developed cutting-edge new metrics for performance and is incorporating them into plans and project evaluation. FDOT has rich Multimodal Mobility Performance Measures & new Accessibility Measure	The lack of freely available data for measuring performance is a recurring challenge in many areas.	Opportunities existing to do more measurement of specific projects (before and after implementation).	States, MPOs, and cities each establish differing measures.

3.6 I-45 Inter-Regional Corridor System

3.6.1 Overview

Interstate 45 (I-45) is a relatively small corridor system that runs entirely in the state of Texas. The corridor connects the City of Galveston on the Texas Gulf Coast to the Houston metropolitan area and continues northward to reach its terminus in the city of Dallas. With no major urban areas between the Houston and Dallas-Fort Worth metros, the corridor primarily serves as a connection between these two cities. I-45 is a major freight corridor, handling a large flow of goods from the Port of Houston as they are shipped across the United States. The I-45 corridor also serves commuters, both locally within the Houston and Dallas areas and between the two metros. Notably, I-45 forms the eastern side of the Texas Triangle, a generally triangular-shaped network of highways (including I-45, I-35, and I-10) that provide intercity access between the Houston-The Woodlands-Sugar Land, Dallas-Fort Worth-Arlington, Austin-Round Rock-Georgetown, and San Antonio-New Braunfels metropolitan regions.

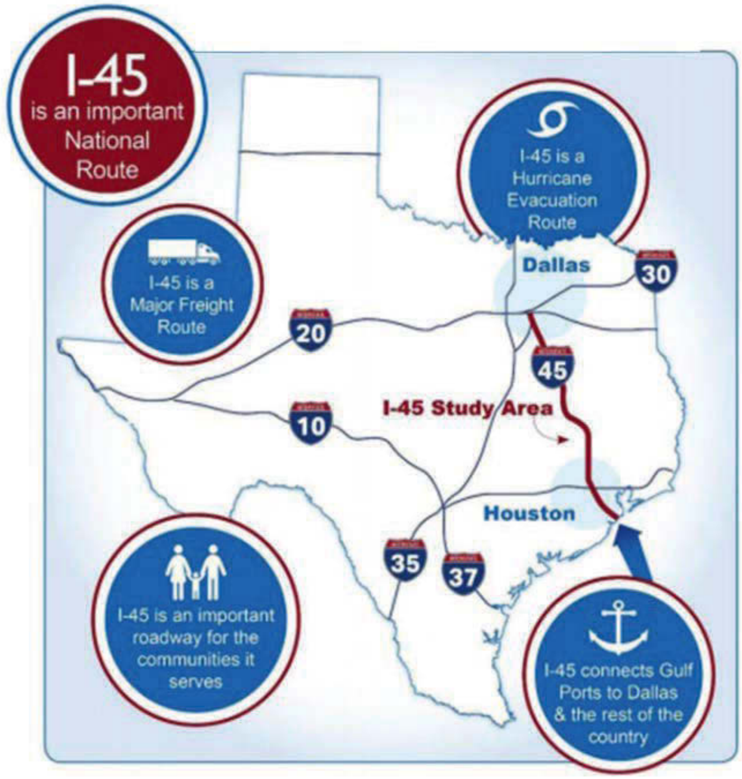
Exhibit 70 **Map of I-45 Corridor**[135]



[135] TranSystems, "Stage 1: Prepare the Freight System - Ftp.dot.state.tx.us," February 28, 2011, https://ftp.dot.state.tx.us/pub/txdot-info/library/reports/gov/tpp/spr/resiliency/resiliency_phase_1.pdf.

The I-45 corridor system is highly multimodal, with sub-systems extending beyond the interstate highway itself. Major rail freight routes run roughly parallel to I-45, and Texas Central Partners, LLC, plans to construct what will be the first high-speed passenger rail route in the United States parallel to I-45 to connect the Houston and Dallas areas. In Houston, light rail transit (red line) runs parallel to an urban section of I-45 for part of its route north of downtown, and Dallas' blue and green lines (also light rail) run in the general vicinity of I-45 (though they do not necessarily serve identical transportation needs here). Additionally, air routes between Dallas and Houston tend to be considered a component of the I-45 corridor. Because the I-45 corridor is so much more than just a highway, it is herein referred to as the Texas East Central Corridor (TECC).

Exhibit 71 **I-45 Study Area**

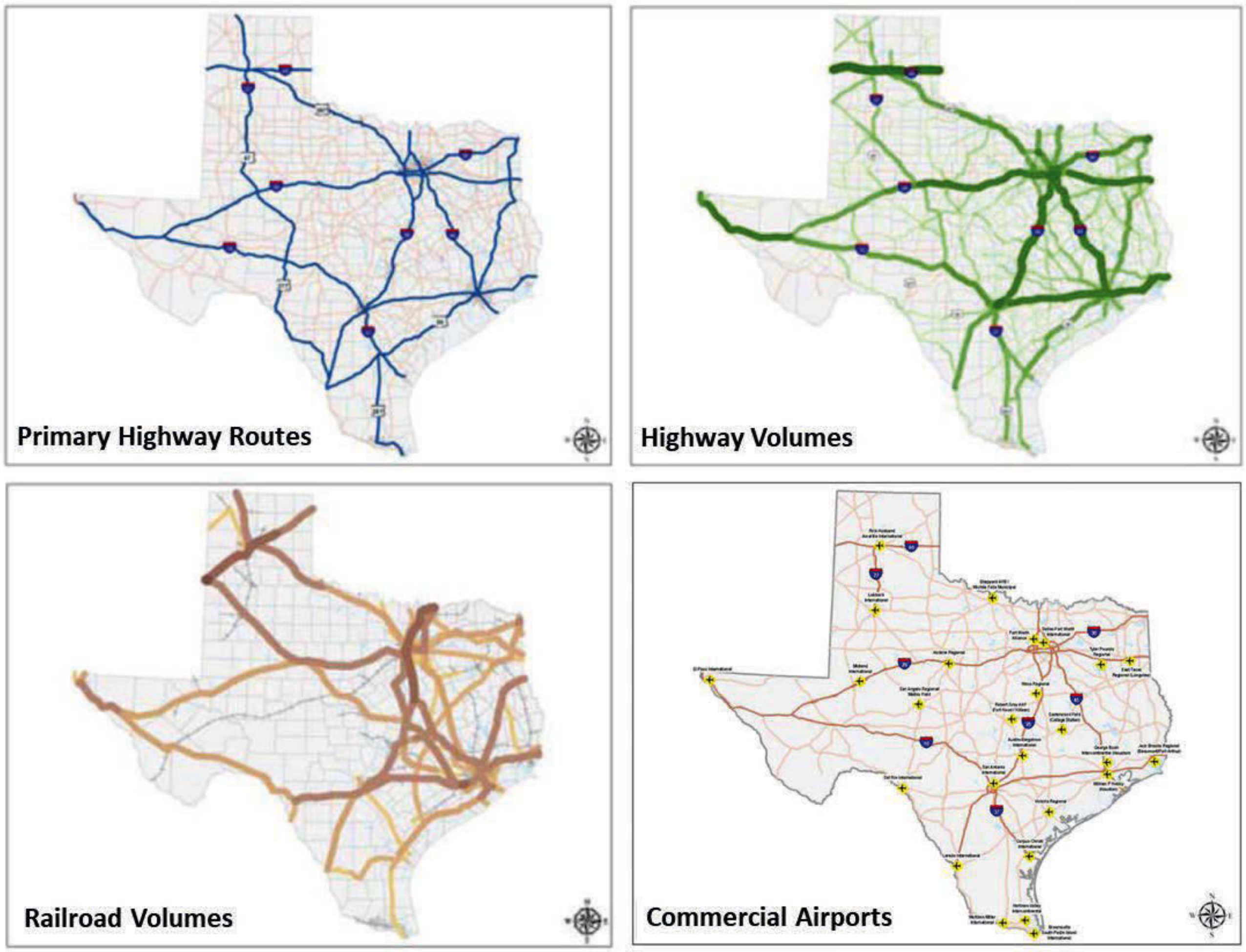


TECC is regarded as an important national route within the Interstate Highway System. Despite its size and geographic characteristics, it serves many purposes. In addition to acting as a major north-south commuter route serving the northern section of the Houston metropolitan area, it provides local mobility for residents in the numerous communities located along the corridor. I-45N is also an important hurricane evacuation route in the Houston and Galveston areas. Additionally, with its connection to the Gulf of Mexico and major intermodal facilities and developments, it serves as a major freight corridor for the Houston area, state of Texas, and United States (TxDOT, 2019, p6).

Exhibit 72 **Map of Freight Facilities in US**[136]

136 "Interim National Multimodal Freight Network State Maps and Tables," U.S. Department of Transportation, accessed October 26, 2021, https://www.transportation.gov/freight/INMFNTables.

Exhibit 73 **Freight Activity Center in Texas**[137]



Key Connections

As a corridor existing entirely within a single state, the TECC primarily intersects with urban highway spurs and other primary Interstate highways, US highways, and state highways in the Houston and Dallas areas. Major highways the TECC intersects include (from south to north): SH-6, SH-146, SH-8 (Sam Houston Tollway), I-610, I-69, I-10, SH-99, SH-105, SH-150, US-190/SH-30, SH-21, SH-OSR, SH-7, US-79, SH-164, US-84, US-287, SH-31, SH-34, I-20, SH-12, US-175, and I-30. Destinations served include Galveston, Greater Houston, and Greater Dallas, as well as smaller municipalities between the urbanized areas. The TECC also provides access to the Port of Galveston, Port of Houston, William P. Hobby Airport (Houston), George Bush Intercontinental Airport (Houston). TECC does not run adjacent to any major airports in the Dallas area, although presumably some freight and people arriving at Dallas Love Field and Dallas-Fort Worth International Airport utilize the TECC.

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[137] TranSystems, "Stage 1: Prepare the Freight System - Ftp.dot.state.tx.us," February 28, 2011, https://ftp.dot.state.tx.us/pub/txdot-info/library/reports/gov/tpp/spr/resiliency/resiliency_phase_1.pdf.

3.6.2 Active Coalitions and Partners

Because of the relatively small-scale nature of the TECC, the corridor is primarily managed by the Texas Department of Transportation (TxDOT) and its Metropolitan Planning Organizations. TxDOT has not organized and thus does not participate in, any larger-scale corridor coalitions. In this way, the TECC is managed in a different way than the longer, multistate corridors considered in other case studies.

TxDOT's I-45 Freight Corridor Plan defines the I-45 (i.e., TECC) freight corridor as "the 276 miles of I-45, plus the multimodal networks supported by arterial highways and collector routes, a class 1 railroad line, terminal railroads, seaports, major air cargo airports, intermodal facilities, inland ports, and associated facilities including many industrial, warehousing, and distribution centers." (TxDOT Freight corridor plan, 2016, p. 1)

Despite TxDOT's recognition of the multimodal nature of the TECC, performance metrics applied to the corridor tend to focus primarily on congestion and safety on the highway facility. TxDOT ranks segments of I-45 in Harris County (Houston area) as the 6th, 12th, 17th, and 30th most congested roadway segments in the state. The 2017 Texas Freight Mobility Plan notes, "Houston has the most bottlenecks of any urban area in Texas, with six of the nine. All six are in central Houston: I-45 at US 59, I-10 at I-45, I-10 at US 59, I-610 at US 290, I-45 at I-610 (north) and I-10 at I-610 (west). These bottlenecks impact activity at Port Houston by adding delay for trucks entering and exiting the state's largest port. This congestion reduces the economic competitiveness of the port by increasing transportation costs in the supply chain. Two bottlenecks are located at highway interchanges in Dallas-Fort Worth: one on I-45 south of Dallas and one on I-35W south of Fort Worth." (TxDOT Freight Mobility Plan, p. 7-16)

Transportation improvements are similarly focused on roadway capacity. According to TxDOT's International Trade Corridor Plan (2018), the major purpose of the I-45 Corridor is to link Port Houston to the Dallas-Fort Worth metroplex. (TxDOT International Trade Corridor plan, 2018, p. 46). Due to its importance to the state economy, the state of Texas spent $746 million on 37 projects along the TECC's highway facility alone in 2017 and 2018. The state's 2019 Unified Transportation Program "shows 56 planned highway projects on the I-45 corridor, 42 are fully funded ($2.2 billion) and two projects are partially funded with approximately $200,000 in funding needed. In addition, 12 projects at an estimated cost of $2.2 billion had no identified funding source in 2018." (TxDOT International Trade Corridor plan, 2018, p. 48).

Exhibit 74 **Projects on I-45 Corridor**[138]

	2017 & 2018		2019		Future	
Project Type	Number of Projects (%)	Cost ($ million) (%)	Number of Projects (%)	Cost ($ million) (%)	Number of Projects (%)	Cost ($ million) (%)
Preservation	12 (32.4%)	21 (21%)	15 (26.8%)	28 (0.6%)	1 (33.3%)	10 (5.4%)
Mobility	9 (24.3%)	451 (60.5%)	9 (16.1%)	2017 (46.1%)	-	-
Bridge	4 (10.8%)	2 (0.3%)	11 (19.6%)	34 (0.8%)	-	-
Safety/ Operational	12 (32.4%)	272 (36.5%)	21 (37.5%)	2,299 (52.5%)	2 (66.7%)	175 (94.6%)
Total	37 (100%)	746 (100%)	56 (100%)	4377	3	185

Dallas MPO's 2018 Regional Transportation plan (RTP) also stresses the importance of freight movement: "The region is the nation's largest inland port, where freight is moved, transferred, and distributed to destinations across the state and around the world. Four major Interstate Highways crisscross the region: I-20, I-30, I-45, and I-35 (including I-35E and I-35W branch routes). The region is a national railroad crossroads and a domestic and international air cargo hub, making it a national logistics hub. Ninety-eight percent of the US population can be reached from North Central Texas within 48 hours by truck. The region has one of the most extensive surface and air transportation networks in the world, providing widespread trade opportunities for the more than 600 motor/trucking carriers and almost 100 freight forwarders operating within the region." (Dallas MPO RTP, 2018, p. 121)

A possible discontinuity in management priorities for the TECC is that Houston's MPO (the Houston-Galveston Area Council, or HGAC) seems to look at the facility mainly as a conduit for commuting within the metropolitan region, which conflicts with other organizations' prioritization of freight movement. HGAC's Congestion Management Process (CMP) lists only goals related to congestion and safety within the region. However, a number of community groups (e.g., Stop TxDOT I-45, the Make I-45 Better Coalition, the Public Interest Research Group, and Air Alliance Houston) oppose TxDOT's plans to expand I-45 north of Houston (formally known as the NHHIP, or North Houston Highway Improvement Project), citing concerns that the project will increase air pollution and flooding in nearby neighborhoods (which have large minority

[138] Texas Department of Transportation, "International Trade Corridor Plan 2018," accessed October 26, 2021, https://ftp.dot.state.tx.us/pub/txdot/move-texas-freight/studies/international-corridor-plan.pdf.

populations) as well as concerns that the project will not ease congestion due to induced demand and development.

Another discontinuity appears to be the controversy surrounding a proposed high-speed passenger rail line in Dallas and Houston. Texas Central Partners, LLC, has proposed building this high-speed rail line that would roughly parallel I-45. Texas Central presents evidence that the passenger railway will ease congestion on I-45 itself, saving travelers time and money, as well as improving safety: "Passengers will be able to travel between North Texas and Houston in about 90 minutes without fear of delay, which will help ease traffic and congestion along the I045 corridor—the second deadliest highway in the US. Ridership studies show the average traveler will save over 120 minutes when making this trip compared with driving or flying."

Few documents produced by state- or regional-level transportation planning agencies refer to the Texas Central Railroad by name, and the company appears to be working with the Federal Railroad Administration much more closely than with state or regional transportation planning agencies. This potentially indicates a reluctance to actively plan for high-speed rail at state and local levels due to the extensive political debate over the merits of this intercity transit system. Some view the project as an expensive waste of money and might wish to see the dollars spent on improving the I-45 highway facility itself instead. Additionally, property rights and eminent domain issues may come up during the land acquisition process for the railroad.

3.6.3 Inter-Regional System-Level Indicators and Measures

A 2019 TxDOT memorandum cited three primary needs/goals for the TECC: 1) Reduce congestion and travel times, 2) improve safety (defined as reducing vehicle crash rates to the state average or better), and 3) improve system connectivity (defined as improving highway interchanges to facilitate bus transit crossings, bicycle and pedestrian crossings, and improve access to "the local roadway network, parallel facilities, and alternative modes of transportation. Many existing interchanges are inadequate to handle existing traffic effectively and safely, a situation that is expected to worsen in the future").

The 2019 TxDOT memo projects changes in AADT, LOS (peak facility and intersection), travel times, travel-time reliability along the highway facility, as well as trends in freight volume and congestion.

Goals listed in the Texas Freight Mobility Plan include:

1. Safety – Improve multimodal transportation safety.
2. Asset Management – Maintain and preserve infrastructure assets using cost-beneficial treatments.
3. Mobility and Reliability – Reduce congestion and improve system efficiency and performance.
4. Multimodal Connectivity – Provide transportation choices and improve system connectivity.
5. Stewardship – Manage resources responsibly and be accountable in decision-making.
6. Customer Service – Understand and incorporate customer desires in decision-making processes and be open and forthright in all agency communications.
7. Sustainable Funding – Identify and sustain funding sources for all modes.

8. Economic Competitiveness and Efficiency – Improve the contribution of the Texas freight transportation system to economic competitiveness, productivity and development. Create opportunities to drive growth in the economic efficiency and productivity of freight movements through targeted investment in the transportation network.
9. Technology – Improve the safety and efficiency of freight transportation through the development and utilization of innovative technological solutions in Texas.

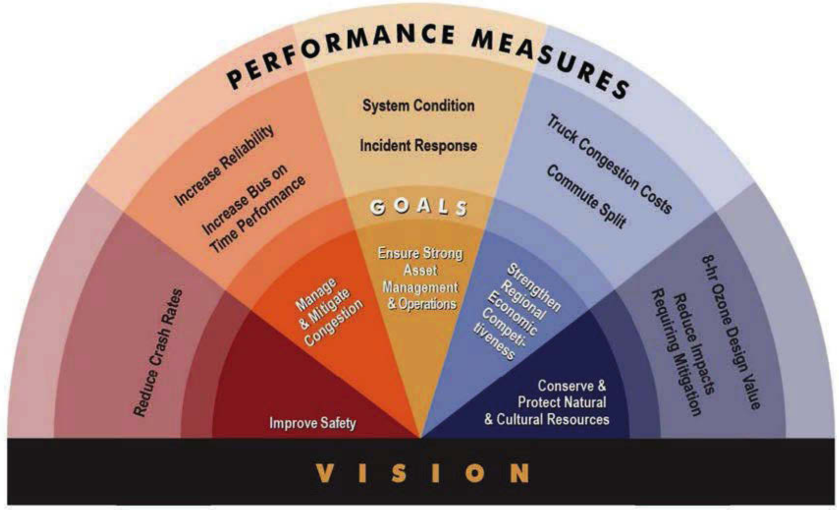
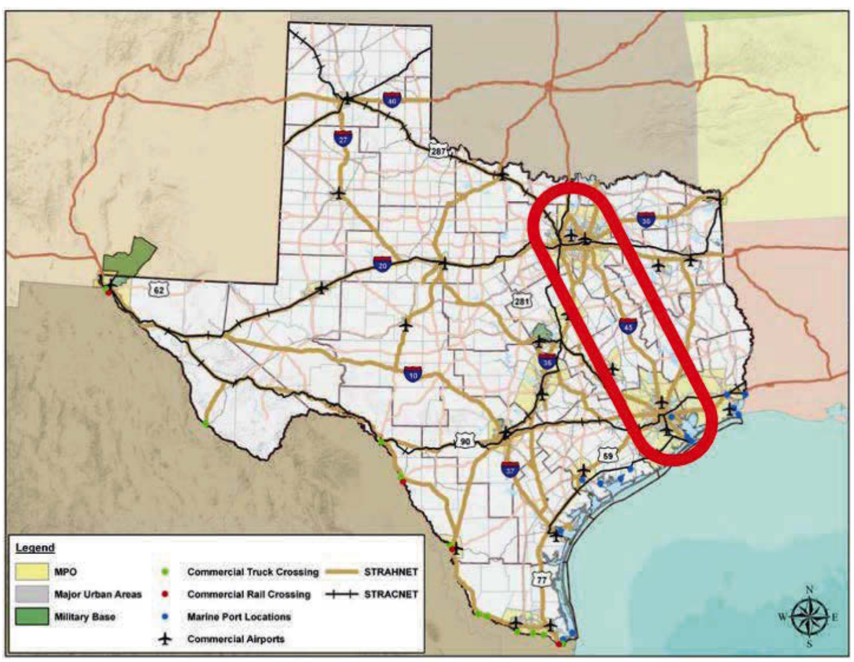


Exhibit 75 **2040 Regional Transportation Plan Goals**

[139] Exhibit 76 **Freight Activity Center**



139 TranSystems, "Stage 1: Prepare the Freight System - Ftp.dot.state.tx.us," February 28, 2011, https://ftp.dot.state.tx.us/pub/txdot-info/library/reports/gov/tpp/spr/resiliency/resiliency_phase_1.pdf.

Selected Observations: Metropolitan Areas

3.6.4 Corridor "Stop" #1: Houston, TX

Houston's MPO, H-GAC, generally treats the I-45 corridor within the Houston area as a commuter highway. Due to the considerable congestion on the corridor, H-GAC set goals and made plans to expand more lanes and toll roads to reduce congestion in its 2045 RTP. Relieving congestion is the primary concern for the Houston metropolitan area.

According to the I-45 Freight Corridor Plan, roadway level of service (LOS, the indicator of congestion at the planning level) ratings suggest a high level of congestion around the Houston region compared to other segments of I-45. The Volume to Capacity ratio (V/C ratio) indicates the volume of traffic on the road versus the capacity of the road over a given time period at the segment level. The highway segment north of Houston is widely viewed as a major bottleneck in the region.

Exhibit 77 **V/C Ratio (LOS) of I-45 Corridor**

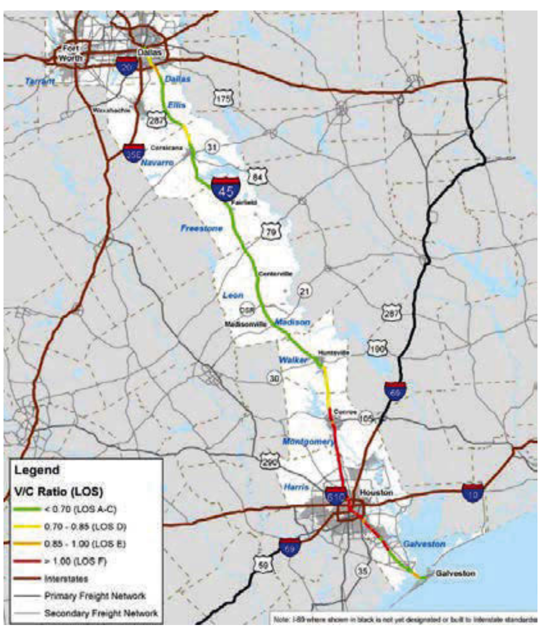
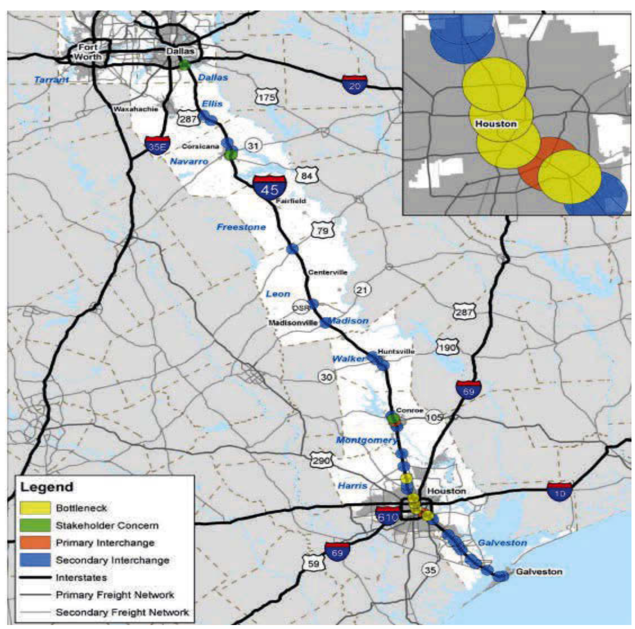


Exhibit 78 **Bottleneck in Houston**



H-GAC's Congestion Management Process (CMP) suggests six "Quality of life goals" to manage congestion within the region:

1) Reduce the rate and severity of crashes for all system users,
2) Improve transportation system reliability across all modes and systems of travel in the region,
3) Reduce the impacts of incidents on traffic flow,
4) Increase opportunities for travelers to use regional and local transit services and participate in Transportation Demand Management (TDM) programs to provide more travel choices,
5) Improve system operational efficiency and accessibility to accommodate freight movement within the region,
6) Reduce emissions through congestion management.

In addition, it focuses on the multimodal network. The Houston MPO's 2017 RTP examines freight movement along I-45 via commercial trucking, railroads, marine freight, pipeline, and air freight. For example, H-GAC tried to expand transit options by expanding the existing service within and outside Harris County. Specifically, its Commuter Rail Service and BRT system are planned to commence in the coming years. In addition, the High Capacity Transit Task Force (HCTTF) at H-GAC works toward the expansion of transit with higher capacity than existing options.

A TxDOT memo emphasizes collaboration with transit providers on improving automobile connectivity to park-and-ride lots along I-45: "Three Park-n-Ride lots are located in the I-45N study area, and two more Park-n-Ride lots are located just west of the study area. In order for Park-n-Rides to remain a reasonable option for travelers, there must be exceptional connectivity between I-45N, Park-n- Rides, and transit service" (p. 26).

The City of Houston suggests the continuous routes that link the suburban population to the regional employment centers, which is an important mobility need and can aid orderly development. The city aims to provide the connected multimodal systems with commercial trucking, marine and freight, and so on.

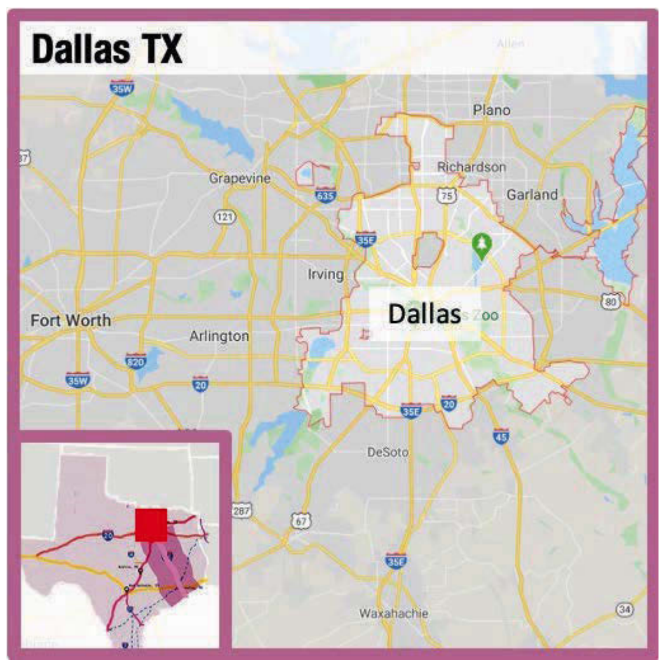
The committee also proposed Transit Corridor Ordinance amendments to promote transit-oriented development and encourage multimodal transportation adjacent to the transit corridors. In addition, as the increased travel demand will be met by inadequate street network capacity and connectivity, it needs to redefine Streets for Multimodal Mobility Solutions. As employment growth is expected along the TECC with population growth, a plan should put more effort into creating a denser urban core through mixed-use development strategies (City of Houston, 2009).

According to Alan Clark, the director of transportation planning at the Houston-Galveston Area Council (H-GAC), the City of Houston has led a sizeable portion of the opposition to TxDOT's plan to expand portions of I-45 in the Houston area. Some city leaders, citizens, and activist groups felt the initial freeway expansion plan would negatively impact minority and low-income communities. The City of Houston has worked to advocate for alternatives to the expansion plan that would confine the freeway to the existing right-of-way, incorporate bicycle and pedestrian infrastructure, and address transit and active transportation issues on frontage roads along the highway facility. The city would also like I-45 expansion to piggyback on major flood control projects that intersect with the freeway corridor. In general, the city is asking TxDOT to consider alternatives that would create the best, most multimodal and flood-resistant corridor possible.

Houston Takeaways

The Houston-area portion of the TECC is undergoing a potentially major shift away from traditional highway corridor planning to one which is more progressive and multimodal. If the City of Houston's concerns influence corridor planning, I-45 and its frontage roads will become a truly multimodal corridor serving commuters, especially in north Houston. It is entirely possible that the I-45 highway facility may not be expanded beyond its existing right of way, with attention and resources instead being focused toward transit and bicycling facilities along frontage roads that increase the throughput of people a corridor with limited space. With this, the Houston region can further its quality of life goals despite a quickly growing population related to the strong state and local economies. The I-45 corridor in Houston will be one to watch in the future, as it could provide a blueprint for the implementation and management of multimodal highway corridors, especially in sprawling Sun Belt cities.

3.6.5 Corridor "Stop" #2: Dallas, TX



Dallas' MPO does not offer its own definition of the I-45 corridor in its 2018 RTP. Rather, it cites the multimodal definition in the 2017 Texas Freight Mobility Plan: "The Texas Freight Mobility Plan, adopted in late 2017, is the Texas Department of Transportation's (TxDOT) governing document for freight transportation planning in the state. The plan includes the Texas Multimodal Freight Network and Texas Highway Freight Network. It also assesses the state's freight transportation assets, goals, policies, and programs. The state, Metropolitan Transportation Organizations, and local governments will all be able to utilize these resources for freight planning. The plan also includes freight-related rail, air cargo, and highway projects that can benefit from federal funding" (p. 122).

Dallas MPO's 2018 RTP describes the importance of highway, rail, pipeline, and air links in the regional freight transportation network. I-45 itself is NOT identified as a "critical freight transportation corridor," but two highways connecting to it on Dallas' south side (I-20 & US 175) are identified as critical urban freight transportation corridors." Dallas MPO's 2018 RTP establishes the need for a high-speed rail link paralleling the I-45 to Houston (p. 152-153).

Dallas MPO's 2018 RTP stresses the importance of freight movement through the region: "The region is the nation's largest inland port, where freight is moved, transferred, and distributed to destinations across the state and around the world. Four major Interstate Highways crisscross the region: IH 20, IH 30, IH 45, and IH 35 (including IH 35E and IH 35W branch routes). The region is a national railroad crossroads and a domestic and international air cargo hub, making it a national logistics hub. Ninety-eight percent of the US population can be reached from North Central Texas within 48 hours by truck. The region has one of the most extensive surface and air transportation networks in the world, providing unlimited trade opportunities for the more than 600 motor/trucking carriers and almost 100 freight forwarders operating within the Region" (p. 121).

The Dallas MPO's 2018 RTP defines principles and goals for the region's freight-transportation network: "Effective freight planning must consider the following five significant freight transportation issues in the North Central Texas region:

- First/last mile connections
- Inadequate infrastructure
- Growing congestion on major regional transportation facilities
- Truck parking
- Safety

To help overcome these freight transportation issues, NCTCOG has multiple regional freight planning goals:

- Seek freight community participation in the planning process.
- Monitor freight traffic through the region to identify potential
- bottlenecks.
- Improve freight movement efficiency to, from, and within the region.
- Promote safety, mobility, and accessibility.
- Reduce the air quality impacts of freight movements.
- Seamlessly incorporate freight considerations in transportation projects.
- Develop and use a sustainable and reliable funding source for freight
- programs and projects.
- Develop a regional freight database.
- Improve railroad safety and reliability" (p. 121-122).

As for the regional collaboration/stakeholders, the Dallas MPO's 2018 RTP describes a working group focused on improving the efficiency of freight movement through the region, including along the I-45: "Freight North Texas is an on-going planning program led by NCTCOG to enhance the safety, mobility, efficiency, and air-quality associated with freight movements within the North Central Texas region. As a part of creating the Freight North Texas Program, in September 2011, NCTCOG staff convened the Regional Freight Advisory Committee, consisting of freight professionals. The Regional Freight Advisory Committee guides North Central Texas Council of Governments staff and regional policymakers regarding freight activities, and the council also provides strategic product and project reviews. The guiding document for Freight North Texas is The North Central Texas Regional Freight System Inventory, published in May 2013. This document highlights policies, programs, and projects needed to improve freight planning and operations in North Central Texas. Several follow-up studies from the report include:

- Freight Congestion and Delay Study (completed in 2016)
- Regional Truck Parking Study (completed in 2017)
- Land-Use Compatibility Analysis (in progress)
- Economic Impact of Freight on the Region (not yet started)
- Freight Project Evaluation System (not yet started)" (p. 122).

In an interview with Natalie Bettger, a Senior Program Manager at the North Central Texas Council of Government (NCTCOG), a somewhat multimodal vision for the corridor was confirmed. Bettger mentioned that a large intermodal freight hub exists and continues to expand in southern Dallas County adjacent to I-45, just south of I-20. This intermodal freight hub serves as a major freight interchange point between rail and truck modes. Beyond intermodal freight, however, Bettger indicated that multimodal options along I-45 are not a large component of the corridor. Bicycle, pedestrian, and transit options are not widely available at present, although NCTCOG is working with area transit providers to determine how transit service can connect workers to the intermodal freight center in the future.

NCTCOG works with TxDOT to plan and manage highway corridors in the Dallas area, including I-45. In terms of operations, TxDOT manages the main lanes of the highway facility throughout the Dallas region, and local municipalities with populations over 50,000 are responsible for managing I-45 frontage roads within their boundaries. In less populated rural areas, especially in south Dallas County, TxDOT takes on the role of managing signals along frontage roads.

Corridor management decisions are made based on a number of commonly used data points, such as congestion, safety, travel time reliability, and land-use. Accessibility is occasionally used as a metric for decision-making, depending on project type. Accessibility measures in the Dallas region generally make use of travel origin data to determine the degree to which people have travel options in a given corridor, with concern typically given to whether people are able to access frontage roads in a variety of ways. NCTCOG and TxDOT each maintain separate travel demand models, and, according to Bettger, TxDOT models do not currently correlate well with regional models. NCTCOG also uses a land-use model to help predict future scenarios and inform corridor planning and management, and this model works in conjunction with NCTCOG's travel demand model but not the TxDOT model. NCTCOG has an entire group dedicated to the development and validation of models, and it may be beneficial for future management of the I-45 corridor to integrate or otherwise reconcile the differences between the two organizations' models. This could perhaps be accomplished more easily if a corridor coalition existed for the TECC, but as stated above, no such coalition currently exists.

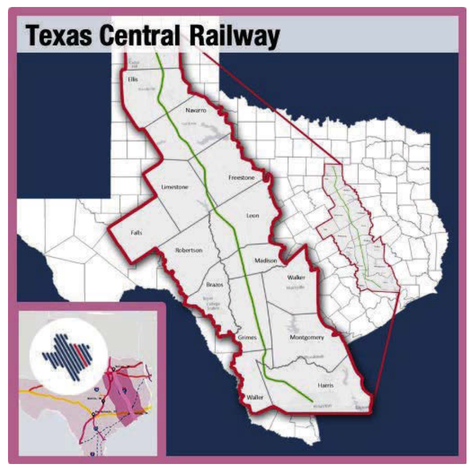
The Dallas region's future vision for the TECC involves focusing on the intermodal freight facility in the southern portion of the region. Better mentioned that transportation in the vicinity of the freight hub is trying to catch up with land-use, as the freight hub has been expanding so rapidly. Bettger specifically mentioned the need for affordable housing near the intermodal freight hub, so that employees working in the freight hub can live a reasonable distance from their job site rather than needing to drive. For those who live elsewhere, NCTCOG hopes to facilitate the expansion of transit services into the area. This will enable workers from other areas of the Dallas region to access jobs at the freight hub in a more sustainable and affordable and less traffic-inducing manner. The ultimate goal in planning and managing the Dallas portion of the TECC in the future is to keep the flow of people and goods moving. This will be crucial not only for commuter access to the freight hub and other employment centers along the corridor but also because the Dallas area's intermodal freight hub is quickly becoming a crucial connection point for freight traveling to and from ports in Houston and Galveston as well as destinations throughout Texas and elsewhere in the region. Shipping and logistics companies will increasingly depend on the ability to move goods to and from the freight hub with minimal and infrequent delays.

Dallas Takeaways:

The Dallas region takes a decidedly more freight-oriented approach to I-45 than the Houston region, largely because I-45 is the main connection from freight distribution centers south of Dallas to ports in Houston and Galveston. The corridor does serve some commuters, but freight interests dominate the discussion in the Dallas region. Plans to make the corridor more multimodal are scarce, with concern mostly centering on how to get workers from Dallas to the multimodal freight hub south of Dallas using transit. The Dallas region recognizes the need to coordinate land-use with transportation in the corridor. NCTCOG does consider how transportation projects interact with and affect land-use during the selection phase. However, transportation options near the region's freight hub currently remain several years behind changes in land-use. The Dallas area may see improvements with the management of the I-45 corridor if the MPO and TxDOT can coordinate or integrate their travel demand models, and the benefits of this may become apparent upon evaluation of other corridors in this study.

3.6.6 Corridor "Stop" #3: Texas Central Railway

The Texas Central Railway is set to become the first high-speed rail route in the United States. Texas Central Partners, LLC, manages the project, and it plans to construct the route between Houston and Dallas, roughly parallel to I-45. The rail right of way will differ from the highway facility, but ultimately the railway will function as another link between the two metropolitan areas and enhance the multimodality of the TECC. This project promises to revolutionize travel in East-Central Texas, with a travel time of 90 minutes between Dallas and Houston. Texas Central Partners suggests that this would save the average traveler 120 minutes compared to driving or flying between the two cities.



When considering the future of the TECC, the Texas Central Railway should be a major consideration due to its potential to dramatically shift the way people travel in the corridor. However, the Texas Central Railway is not mentioned directly by corridor planning documents from TxDOT of the MPOs serving Houston and Dallas. This could be the result of perceived political controversies surrounding the railway. The Texas Central Railway website suggests that the rail line will cost over $12 billion to plan, design, and construct. Undoubtedly some will perceive this as money that could have been spent on improving the I-45 highway facility instead.

An interview with Alan Clark, the director of transportation planning at the Houston-Galveston Area Council, revealed that planners in the Houston region do not expect the Texas Central Railway as planned to affect commuter traffic on I-45. The general consensus at H-GAC is that the railway would only significantly affect commuter traffic if Texas Central built commuter rail-like stations in the northern Houston suburbs. Although this would slow travel speed and time on the railway, these stations would make the train a useful local commuting option. In addition to the lack of commuter rail-like stations, the cost to ride the Texas Central Railway is expected to be fairly high, likely similar to airfare between Houston and Dallas. For these reasons, Clark believes the Texas Central Railway will likely function as an alternative to air travel between Houston and Dallas rather than an alternative to driving through the corridor. Airlines serving this route generally do not view the Texas Central Railway as a threat, according to Clark, because the air route between the two cities is already heavily served and passenger load factors are consistently high.

An economic impact study produced for Texas Central Partners, LLC, estimates that the total economic impact of the rail line by 2040 will eclipse $74 billion, more than covering the initial investment in the high-speed rail infrastructure (Texas Central Partners, LLC, Analysis of Economic, Employment, and Tax Revenue Impact 2015-2040). This metric is a primary argument being made in support of the railway.

Other corridor impact metrics to be considered with the Texas Central Railway include travel time, congestion, and safety. As mentioned above, the railway promises to reliably reduce travel times between two major cities in Texas, meaning it could set a new standard for passenger travel in the corridor. With fewer people potentially traveling on highway facilities in the TECC, congestion could improve as well. Alternatively, the railway can function as an alternative for travelers wishing to avoid congestion in the corridor. Finally, the railway may increase the safety of travel in the corridor, especially considering the TECC highway facilities are recognized as particularly dangerous on many segments. For this reason, safety will be an important consideration for planning organizations at different levels as they attempt to incorporate the railway into future visions of the corridor.

The addition of the Texas Central Railway to the TECC will undoubtedly be closely watched by transportation agencies around the country, particularly in areas where high-speed rail connections could be effective transportation solutions. High-speed rail may not work in every corridor, especially those too long or short to support high-speed rail. However, medium-distance routes comparable to the distance between Houston and Dallas could one day implement high-speed rail if the Texas Central Railway proves successful. With Texas Central Partners, LLC, being a private company, this model could also prove to be the most effective high-speed rail construction strategy compared to construction by state governments, as in California. High-speed rail could induce a mode shift away from auto travel for travelers needing to move between the Dallas and Houston areas, which would, in turn, allow I-45 to function more as a freight corridor than it already does.

TCR Takeaways

The Texas Central Railway is on track to up-end the low expectations for the success of high-speed rail in the United States and fundamentally change how some people travel in the TECC. Interestingly, experts in Texas do not expect the Texas Central Railway to compete directly with automobile travel, but rather with air travel. To date, air travel has been the primary alternative to driving between Houston and Dallas, and air routes have become congested. The Texas Central Railway may relieve the strain on airlines. In theory, the railway could also compete with automobile traffic, especially among people traveling for business between the two cities. In addition to offering faster travel between the two cities, it will enable people who would otherwise drive to remain connected throughout their journey and get work done in the process. These benefits may attract a significant portion of people who might otherwise drive in the corridor, but the major parties involved in managing the TECC tend to not give the railway much consideration. Whatever the reasons for this, it may be beneficial for MPOs and TxDOT to plan for scenarios in which the Texas Central Railway does significantly impact passenger vehicle traffic in the corridor. Because high-speed rail is not common in America, it is perhaps difficult to visualize future scenarios. The closest analogous corridor in America is the section of I-95 between Washington, D.C., and Boston, where Amtrak's Acela Express train roughly parallels the highway facility and serves similar destinations. Considering how I-95 corridor management in the Northeast takes pseudo-high speed rail into account (i.e., traffic impacts, land-use impacts, economic impacts, etc.) may help inform the planning and management of the I-45 corridor in Texas once the Texas Central Railway is completed.

3.6.7 Other Selected Observations

State-level actions

"TxDOT is developing technology-based congestion mitigation strategies. For example, the Texas Connected Freight Corridors project seeks to create a sustainable connected vehicle deployment in Texas by showcasing connected vehicle applications along with the Texas triangle, connecting Houston, San Antonio, Austin, and Dallas/Fort Worth, using I- 35, I-10 and I-45 as proving grounds. The project will deploy vehicle-to-vehicle and vehicle-to-infrastructure applications to help improve safety and mobility and reduce bottlenecks" (Texas Freight Mobility Plan, 2018, p. 7-18).

3.6.8 I-45 System Takeaways

Management Without Formal Coalitions: As a relatively short corridor that exists entirely within Texas, the TECC is unique in many ways. Management of the corridor might be less complicated since the entire corridor is overseen by TxDOT. Because interstate coordination is not required, TxDOT can make decisions for the corridor without considering the priorities and needs of other states. The corridor's short length also provides fewer potential partners for multi-jurisdictional coalitions. To some degree, however the collaboration between TxDOT, the Houston and Dallas MPOs and the Texas Central Railway function as a de-facto coalition.

Infrastructure Supply and Travel Demand Management Tactics and Impacts: With population growing rapidly along the corridor, particularly in the Dallas and Houston areas, many opportunities exist to coordinate land-use and transportation. New, denser housing will likely be necessary to support growth, and the I-45 corridor should evolve to meet these needs. With traffic congestion already a major concern in Dallas and Houston, transit options along the corridor (likely running along frontage roads) may help to ease future strains on the roadway without spending time and resources expanding the freeway itself. High-quality transit options along I-45 would also likely lead to transit-oriented development, which can bring about diversification of land-use that enables people to live closer to jobs and amenities, further reducing strain on the roadway network. Houston, in particular, seems to be heading towards more pro-active demand management with its proposal to limit the expansion of the I-45 right of way in north Houston, instead focusing on transit and active transportation investments. Dallas also considers transit, but in a more limited way that would mostly serve people commuting from residential areas closer to central Dallas to the multimodal freight hub in south Dallas County.

Passenger Multimodal Strategies: The Texas Central Railway also promises to give Texans an additional mode choice for travel between Dallas and Houston. The TECC overall serves a region experiencing great economic success and high population growth, and the corridor represents a chance for the state of Texas and two of its largest metropolitan regions to work together to reimagine how a modern corridor can function and be managed with longevity in mind to provide equitable transportation options for all stakeholders.

Measurement of Impacts: In effect, the partners on I-45 have focused either on traditional measures of VMT, VHT congestion, delay, safety and air quality consistent with MPO and DOT targets – without the use of the exquisite dashboards used elsewhere. However, the strong focus on both passenger and freight multimodal solution sets – especially involving inter-modal rail and transit planning, combined with new growth management policies make the region a very strong candidate for the testing of 7-D report cards and benchmarks for using demographic, destination access, modal diversity and other “D-variable” considerations.

Exhibit 79 **I-45 System Takeaways**

Topic	Takeaways			
	Strengths	**Weaknesses**	**Opportunities**	**Challenges**
Truck parking	-Dallas Region completed a regional truck parking study in 2017 -TxDOT has conducted a statewide truck parking study	-Majority of truck parking locations along I-45 are over capacity, leading to truck drivers parking in unauthorized places	-Lots of open rural space between Houston and Dallas means expansion and new construction of parking facilities likely will not impact many people	-Limited buildable space in urbanized areas -Rapid expansion of freight industry in Dallas and Houston is difficult to keep up with
Planning & Environmental Linkage (PEL)	-City of Houston is asking TxDOT to consider flood mitigation projects as it expands I-45 -City of Houston wants TxDOT to keep I-45 improvements confined to existing ROW to minimize property takings in low-income areas	-TxDOT proposals for I-45 in north Houston would likely expand ROW	-TxDOT, H-GAC, and City of Houston have an opportunity to create a truly multimodal corridor with I-45 reconstruction in north Houston -I-45 could be a prototype for highway improvements elsewhere in Texas as metropolitan areas respond to a population boom and associated travel demand	-TxDOT, H-GAC, and City of Houston do not fully agree on the future of I-45
Corridor Planning & Funding	-I-45 corridor exists entirely within one state, so it falls under the control of just one DOT -Project funding decisions at H-GAC and NCTCOG tend to be unanimously decided by their respective transportation policy boards -MPOs in Dallas and Houston put significant effort into creating and validating travel demand models	-Local and state entities often disagree on highway planning -MPO travel demand models and not always in sync with TxDOT models -No corridor coalition	-MPOs and TxDOT could collaborate to develop a unified travel demand model -Creation of corridor coalition	-Discontinuity in priorities between TxDOT and MPOs -Lack of support for corridor coalition since I-45 does not travel between states

	Strengths	Weaknesses	Opportunities	Challenges
Public-Facing Open Data & Dashboards	-TxDOT runs an open data portal with many datasets -H-GAC offers a large variety of GIS data and other datasets online; also has an online request form for regional growth forecast data -NCTCOG offers a large variety of GIS and other data on its website -Data at all organizations is free to download	-Limited availability interactive data viewing applications	-Regularly update data as it becomes available -Increase utilization of interactive data displays, such as maps and dashboards	-Potential political disagreements over whether data should be free and open to the public (not currently a major concern)
Corridor Management - Hazardous Incidents (Hurricanes, Snowstorms, etc.)	-TxDOT and H-GAC acknowledge I-45 as a hurricane evacuation route -I-45 southbound lanes can be shifted to northbound for hurricane evacuation	-Plans for I-45 expansion in Houston lack consideration for flood control -Even with all lanes northbound, I-45 can become very congested during evacuations	-City of Houston has asked TxDOT to consider flood control projects that intersect with the I-45 reconstruction areas	-I-45 cannot be expanded as a hurricane evacuation route (or for other purposes) without taking adjacent land from property owners
Connected Vehicles (CV)/Integrated Corridor Management (ITS)	-TxDOT has an in-house C/AV task force -NCTCOG and H-GAC each plan for C/AV technology in their regions	-Many unknowns with C/AV technology -Expansion of C/AV technology could undermine efforts to expand transit, control sprawl, lower VMT, etc.	-Integration of shared C/AV technology to reduce auto ownership rates and congestion	-Unwillingness to adopt C/AV technology among the general public
Performance Measures	-TxDOT and MPOs use standard performance metrics such as travel time index, mobility, safety -Accessibility sometimes used as a metric	-Limited use of metrics beyond standard highway performance metrics	-Integration of more progressive/non-traditional metrics into project selection and corridor management	-Disruptions to the status quo paradigm of corridor planning

3.7 I-15 Corridor System

3.7.1 Overview

This case study defines the I-15 system as one of the four corridor systems for case study development. The I-15 Corridor is Approximately 1,470 miles long extending traveling through California, Nevada, Utah, Idaho and Montana. Traveling southwest to northeast, the I-15 Corridor begins its journey in San Diego, CA, where it connects to the I-5. I-5 and I-15 parallel one another north to the LA basin, with I-5 hugging the coast and I -15 running inland to the north and west. I-15 then turns northeast, extending through Las Vegas NV, and St. George UT. North of St. George is the beginning of I-70, which runs to the east coast. I-15 itself continues north into Salt Lake City, where it then intersects with I-80. The corridor continues north through Ogden, UT, Idaho Falls, ID and then Butte, MT, where it intersects with I-90, another focus corridor. I-15 continues north to its terminus at the Canadian border.

Exhibit 80 **UDOT 2017 Freight Brochure I-15 (highlighted)**

The entire corridor is part of the larger CANAMEX Corridor complex. This case example focuses on the corridor between Long Beach, CA and Salt Lake City, UT, but also considers localized effects in places like Logan City, which is 82 miles north of Salt Lake City and approximately 28 miles to the east of I-15. Logan was selected because of its unique corridor management efforts, which have a heavy emphasis on land-use impacts. Error! Reference source not found. shows the overall orientation of the I-15 corridor in the western US.

Key connections

The corridor connects multiple trade centers in the western US across relatively long inter-city distances. Much of the land surrounding the I-15 system is un-developable on account of mountains and environmental constraints, making its inter-city and local impacts easier to isolate than other systems like I-90/94 or I-95/85. Its relationship to the Port of Long Beach warrants attention. Neither the I-5 nor I-15 connects directly to the Port of Long Beach warrants attention.   Terminal Island Facility in Long Beach, CA. The primary interstate connection to the terminal facility is I-710. From this connection, I-710 orients north to a connection with I-10. I-10 connects with I-5 and I-15 to the east. The next interstate connections to the I-15 corridor, prior to Salt Lake City, are I-40, at Barstow, CA and I-70 in central Utah. North of Salt Lake City, the I-15 corridor connects to I-84 in Tremonton, UT, and eventually to the I-90 corridor in Montana, another corridor case study.

Exhibit 81 All Interstate and US highways connections

California	
-5	On the Barrio Logan, San Diego
I-805	ON the North Park-City Heights, Sand Diego
I-8	On the Mission Valley East Grantville, San Diego
I-215	Murrieta
US-395	Hesperia
I-40	Barstow
Nevada	
I-215	Enterprise
I-515/US-93/US-95	Las Vegas
Utah	
I-70	Cove Fort
US-50	Holden
US-6	Santaquin
US-189	Provo
US-89	Lehi, Salt Lake City, North Salt Lake City
I-215	Murray
I-84	Riverdale
US-191	Perry-Brigham City
Idaho	
US-91	Virginia, Blackfoot
US-30	McCammon
I-86	Chubbuck
US-26	Blackfoot
US-20	Idaho Falls
Montana	
I-90	Butte
I-115	Butte
US-12	Helena
US-287	Helena
I-315	Great Falls
US-89	Great Falls
US-2	Shelby

Major metro areas and associated cities:

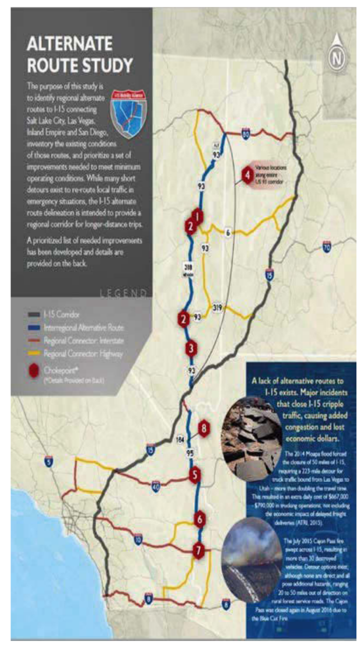
- Los Angeles/Long Beach/Anaheim- CA
- Riverside/San Bernardino/Ontario- CA
- Las Vegas/Henderson/Paradise- NV
- St. George- UT
- Provo/Orem- UT
- Salt Lake- UT
- Ogden/Clearfield- UT

3.7.2 Active Coalitions and Partners

I-15 Mobility Alliance

The I-15 Mobility Alliance includes a select group of public and private sector stakeholders collaborating on the vision for I-15 through the states of Arizona, California, Nevada, and Utah.[140] Organized in 2009, the I-15 Mobility Alliance developed the first I-15 Corridor System Master Plan in 2012, updated in 2017, to provide policy and decision-makers with a strategic action plan that defines future transportation infrastructure, and supports national, regional, and local approaches to improve freight delivery and relieve congestion for years to come. Individuals within the four states and beyond invest their time and resources to keep this economic artery of the west-flowing. The Alliance is led by the senior leadership of the Arizona, California, Nevada and Utah departments of transportation. The alliance's initial focus was on data sharing, truck parking, smart truck parking, and weather and incident management. The alliance is initiating an additional phase that will continue to work on improving data sharing and incident management as well as coordinate planning activities.

Exhibit 82 Mobility Alliance Alt Rt Study (2017)



The goals of the Alliance include:

- Reduce or eliminate congestion impacting the interregional movement of people or goods
- Improve interregional travel time reliability of people or goods movement
- Improve the safety of the interregional movement of people or goods
- Construct projects in a manner that respects and honors the unique goals/objectives/standards of each sponsoring community/entity

The Alliance partners come from state and local transportation agencies, local and interstate commerce, port authorities, departments of aviation, freight and passenger rail authorities, freight transportation services, providers of public transportation services, environmental and natural resource agencies, and others, see **Exhibit 84**.

In the urban areas, there are a number of alternative routes to I-15, outside of those urban areas. However, there are not many options given the rural nature of the west. In September of 2014, a flash flood washed out a 50-mile stretch of I-15 near the Nevada/Utah Border. As a consequence, the I-15 Mobility Alliance conducted an assessment to look for alternative routes to I-15 in the area.

The Provo/Orem BRT Corridor Partners are not an officially sanctioned corridor coalition, yet the partners have worked to develop multimodal solutions for the corridor. They have established a set of performance measures and processes, albeit limited in duration, to evaluate the performance of corridor improvements. The partners include the Mountainland Association of Government, the Utah DOT, the UTA, the Cities of

140 "Home - I-15 Mobility Alliance," I-15 Mobility Alliance, January 9, 2020, https://i15alliance.org/.

Provo and Orem, and the University of Utah's Metropolitan Research Council, in cooperation with Brigham Young University.

The partners implemented BRT and roadway improvements in the corridor and wanted to understand what happened to travel patterns, mode share and land-uses in the corridor after the program was completed. The partners prepared an existing conditions report and then agreed to go and evaluate the corridor one year, two years, and three years after completion to assess performance. The assessment is still underway, and the project was completed in August of 2018.

Logan City Main Street Partners

The City of Loga, the Cache Valley MPO and the Utah DOT came together to develop a master plan for Logan's main street. The Mainstreet is a US highway (US-89/US-91) under the jurisdiction of the Utah DOT. The Utah DOT, the City of Logan, and Cache Valley MPO were concerned that the one-way couplet solution did not have community buy-in, so they decided to take a step back and use UDOT's new corridor planning process to establish contextually based goals for the corridor. The goals included land-use goals, economic development goals and open space goals. From these goals, the partners then turned to the transportation network and a set of goals for the network that would support the broader community goals. The partners engaged the business community, neighborhood groups and the larger public to help develop and gain buy-in to the community and transportation network goals. The project is still underway. The partners are in the process of establishing corridor objectives and performance measures/evaluation criteria for an upcoming corridor study.

Alameda Corridor Transportation Authority

In the late 1980s, there was a group of leaders in the region known as the **Alameda Corridor Task Force, which concluded that "a Joint Powers Authority should be created to have design and construction responsibility for the Alameda Corridor, and the Alameda Corridor Transportation Authority (ACTA) was created in August of 1989.**[141] **Project objectives explicitly stated these dual purposes:**

> "The purpose of the Alameda Corridor project is to facilitate access to the ports through the year 2020 to accommodate anticipated growth, thereby reducing highway traffic congestion, air pollution, vehicle delays at grade crossings and noise in residential areas."[142]

[141] "History - Who We Are - Acta," Alameda Corridor Transportation Authority, January 6, 2021, http://www.acta.org/about/history.asp.

[142] "The Alameda Corridor Rail Project," Centre For Public Impact (CPI), accessed October 26, 2021, https://www.centreforpublicimpact.org/case-study/alameda-corridor-rail-project/.

3.7.3 Inter-Regional System-Level Indicators and Measures

The impacts of the I-15 system covered in this SWOT are largely managed by local or regional coalitions in Logan, the Salt Lake City/Wasatch Front Region, Utah County, Las Vegas and Los Angeles (with respect to the Alameda Corridor ancillary tributary. Because of (1) the desert and mountainous nature of I-15, (2) the distance between communities served by the corridor and (3) its shorter length than I-90/94 or I-85/95, the I-15 system provides an example of a system which has fewer continuous and multijurisdictional coalitions, as have been observed in the other systems. The I-15 system however does provide an exemplary understanding of effective local and regional impact measurement regimes, how they are used in managing the corridor at different levels. The system also provides helpful examples of how ancillary and tributary systems (like Logan's arterials and the Alameda/Long Beach system) relate to the effectiveness of a larger national system to access both local communities and an international gateway.

Selected Observations

3.7.4 Corridor "Stop" #1: Main Street in Logan, UT

The Logan area in Cache County is small on the national scale, with about 142,000 residents in 2019. It is about 20-miles east of I-15 but is heavily dependent on I-15 for north-south freight and for connection to the greater Wasatch Front. Cache County does not have a freeway and instead depends on Main Street for both long-distance and short-distance trips. Because of this, Main Street serves high volumes of traffic, while at the same time it is facing new calls for walkability and more intense land-use development. The corridor is a good candidate for reviewing how UDOT and the local community are addressing multi-disciplinary corridor management.

Exhibit 85 shows how Main Street has a very nice historic district with shared-wall buildings that abut the sidewalk, but a lot of cars and hardscape that detract from an otherwise walkable environment. The right-of-way width is a very large 130 feet. But despite having significant space for wide sidewalks and some trees, the business community does not consider it very pedestrian-friendly largely due to a 5-lane cross-section with parking on both sides that serves a huge 45,000 vehicles per day under extremely congested conditions – a lot of hardscape with a lot of cars. This is a case where the community is hoping that corridor

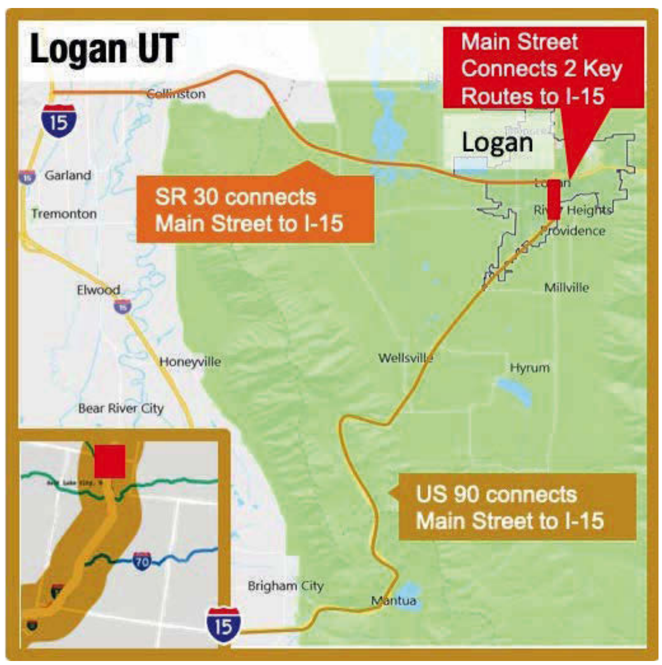
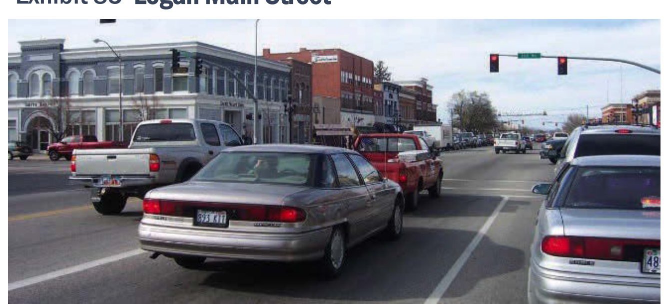


Exhibit 83 **Logan Main Street**



management can address more than just chronic congestion, but also focus on elements that will help them achieve a better pedestrian experience, and achieve their mixed-use, higher density land-use objectives for downtown.

Exhibit 86 shows how the city is overly dependent on Main Street largely because too many trips are forced into the Main Street corridor to avoid a canyon barrier. Pedestrian-enhancement solutions have been proposed in the past, such as narrower travel lanes and planted medians where possible, but they have never been feasible due to traffic management needs. However, Main Street also has a parallel roadway that could be used to create a one-way couplet. Doing so would enhance both the ability to manage more traffic and at the same time improve the pedestrian environment by reducing the amount of hardscape since a center left-turn lane would not be needed.

Exhibit 85 shows the current Main Street versus how it might look in a one-way couplet configuration (with a similar cross-section on 100 West).

Exhibit 84 A canyon barrier (red) forces trips into the Main Street Corridor (Purple)

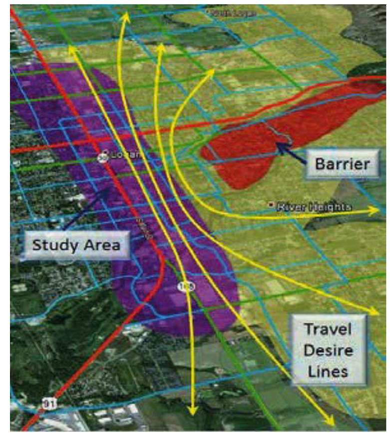


Exhibit 85 **Existing and One-Way Couplet Cross Sections**

Exhibit 86 **Change in Pedestrian Environment**

Exhibit 88 shows the improvement in walkability that is possible with the project. An ArcGIS plugin called "Viacity" was used to estimate Before/After effects. Red parcels are where walking is deemed to be "less pleasant, less safe, and/or slow" relative to green parcels. Yellow is average.

If the project is implemented as planned, the "After" diagram shows that walking on Main Street becomes entirely green or yellow with no red, so similar to most other places in the city. The change diagram shows parcels that have improved due to the project. Data that was used to create the measure included:

- Before/After signal cycle lengths (shorter cycles after = faster pedestrian cross times)
- Before/After pedestrian crash modification factors (one-way is safer due to slower after speeds and fewer conflicts)
- Before/After pedestrian right-of-way allocated to pedestrians and roadside amenities, as well as an expectation of walk-oriented development that would occur: This was a qualitative and "faith-driven" estimate that if you build it, the buildings will come. It was meant to show that walking would be more pleasant and interesting than before.

With three basic measures (speed, safety, and quality of experience), each was weighted for a third of the expected overall benefit.

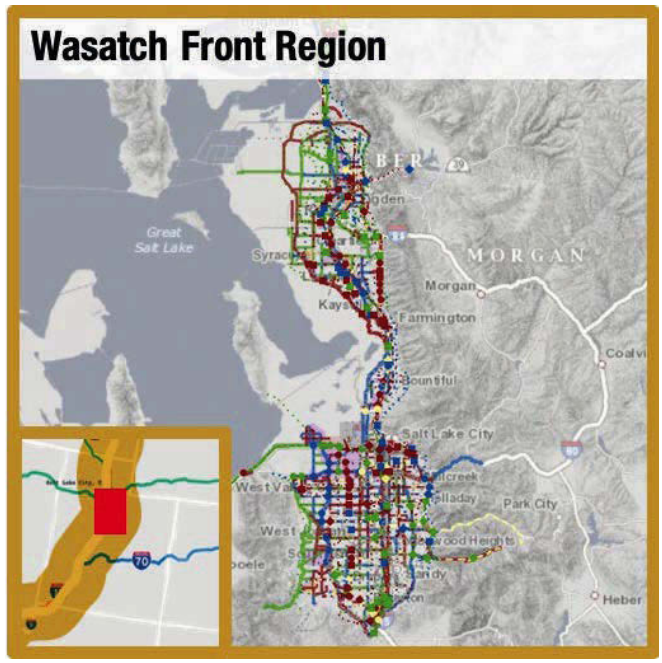
Stepping Back to Planning and Environmental Linkage

UDOT, the City of Logan, and Cache Valley MPO were concerned that the one-way couplet solution did not have community buy-in, so they decided to take a step back and use UDOT's new corridor planning process to establish contextually based goals for the corridor. The goals included land-use goals, economic development goals and open space goals. From these goals, the partners then turned to the transportation network and a set of goals for the network that would support the broader community goals. The partners engaged the business community, neighborhood groups and the larger public to help develop and gain buy-in to the community and transportation network goals.

Now that the community is in general agreement about the general hopes they have for the area, a new PEL-compliant corridor study is underway now to express those hopes as specific objectives, and select evaluation criteria/performance measures by which potential solution-set elements will be judged. The "Stratified Return on Investment" approach recommended in the new *NCHRP 917 Rightsizing Guidebook* may be utilized to help bring various stakeholders together to create weighting factors for various objectives and thereby express the relative importance of objectives such as minimizing delay vs. maximizing walkability vs. minimizing costs. Once there is agreement on objectives and measures, and the relative importance of each objective and measure, many potential solution set elements can be evaluated with greater odds of stakeholder acceptance because they agreed to support project elements that have a high return on investment with regard to their weighted objectives. It is anticipated that the partners will establish an agreement that outlines each party's responsibilities for meeting the broader community and transportation network vision of the corridor. In essence, such an agreement could serve as a means of formalizing a corridor coalition that will oversee the implementation of the vision and manage the corridor in the future.

3.7.5 Corridor "Stop" #2: Wasatch Front Region

The Wasatch Front region surrounding Salt Lake City Utah is bisected by I-15 which serves as its lifeline to all points north and south. Because the Wasatch front and surrounding mountains both (1) constrict developable land and potential north-south corridor alignments and (2) create an emissions "basin" surrounding the region, I-15 in Utah represents a highly educational case in corridor impact. The impacts and strategies associated with managing I-15 in Utah illustrate the convergence of (1) a highly constrained highway mobility challenge (in an area where highway facility capacity cannot be readily expanded), (2) an ongoing problem of utilizing limited clean air, thereby a need to minimize emissions or delay, (3) a complex regional government environment with state, local and regional partners across various modes and (4) a highly diverse and growing set of land-use and multimodal solutions to enable I-15 to serve the region and its communities for both people and freight.



Utah's Wasatch Front: Salt Lake, Ogden, Provo, Logan Metro Areas

Exhibit 87 **Wasatch Front Population**

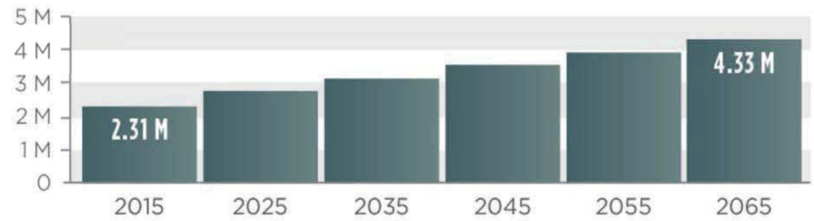
MSA Name	2019 Population
Logan, UT Metro Area	142,000
Ogden-Clearfield, UT Metro Area	684,000
Salt Lake City, UT Metro Area	1,233,000
Provo-Orem, UT Metro Area	648,000
Wasatch Front Total	2,707,000

Utah's Wasatch Front is about 140 miles long, generally 2 to 18-miles wide, and built around I-15 as its major backbone. It consists of four Metropolitan Statistical Areas, listed here from north to south. Salt Lake City itself is the state's largest city with a population near 200,000. The Metropolitan Planning Organization (MPO) for both the Salt Lake area and the Ogden-Clearfield MSA is the Wasatch Front Regional Council (WFRC). The

MPO for Provo-Orem is the Mountainland Association of Governments (MAG). The MPO for Logan is Cache MPO.

All MSAs are experiencing fast growth relative to the nation at large. Between 2015 and 2019, Provo/Orem grew at an average annual rate of 2.81%, while Salt Lake grew at 1.30%. At the same time, the MSAs are growing together into one large metro area, and growth is expected to accelerate in the medium and long term. Exhibit 87 shows population growth numbers for the entire Wasatch Front through 2065, essentially the area will nearly double in population by that time.[143]

Exhibit 88 Wasatch Front Population Growth



Source: Kem Gardner Policy Institute, University of Utah

Land-use

Generally, Wasatch Front communities are a mix of urban, suburban and ex-urban land-uses. There is a considerable effort from the MPOs to influence current and future land-use practices. Both WFRC and MAG jointly work with local governments, business and modal agencies in the creation of the land-use assumptions that underlie the area's long-range planning. The land-use framework is called Wasatch Choice for 2050.[144] It is focused on converting auto-oriented commercial areas into walkable mixed-use Activity Centers and walkable boulevards, while also acknowledging that a significant amount of future development will emerge under the traditional suburban pattern of Euclidean zoning.

See Exhibit 91 for the Wasatch Choice for 2050 partners, and Exhibit 92 and Exhibit 93 for a graphic depiction of the vision and a map of proposed economic development, respectively. MAG and WFRC both use the same travel demand model and have developed a land-use model, a variant of UrbanSim, called the Real Estate Market Model, or REMM. REMM gives the MPOs the ability to estimate how transportation network investments will impact, positively or negatively, their walkable land-use objectives. It is also possible to learn how land-use and economic scenarios will impact transportation. REMM is also used to allocate future population and employment in travel demand models TAZ structure.

[143] "David Eccles School of Business," Kem C. Gardner Policy Institute, February 27, 2019, https://gardner.utah.edu/.

[144] "Wasatch Choice 2050 3," Wasatch Front Regional Council, accessed October 26, 2021, https://wfrc.org/vision-plans/wasatch-choice-2050-3/.

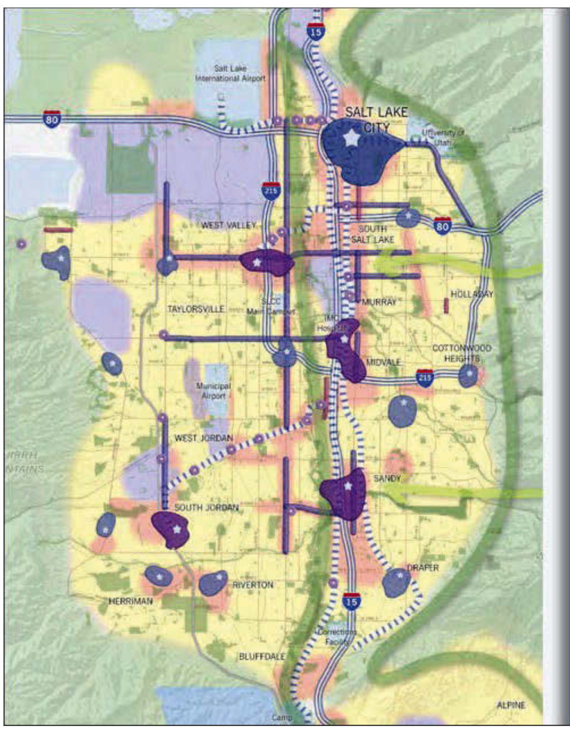
Exhibit 89 **Wasatch Partners**

Partners of the Vision

WASATCH CHOICE 2050

Wasatch Front Regional Council · APA UT · Envision Utah · Kem C. Gardner Policy Institute, The University of Utah · Metropolitan Research Center · Mountainland Association of Governments · Salt Lake County · Utah Association of Counties · UDOT · Utah League of Cities and Towns · UTA

Exhibit 90 **Wasatch Choice for 2050 Land-use and Transportation Vision**

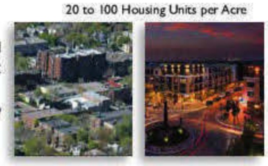


Wasatch CHOICE for 2040

Metropolitan Center — 20 to 200 Housing Units per Acre

Downtown Salt Lake City is the metropolitan center, serving as the hub of business and cultural activity in the region. It has the most intensive form of development for both employment and housing, with high-rise development common in the central business district. It will continue to serve as the finance, commerce, government, retail, tourism, arts, and entertainment center for the region.

Urban Center — 20 to 100 Housing Units per Acre

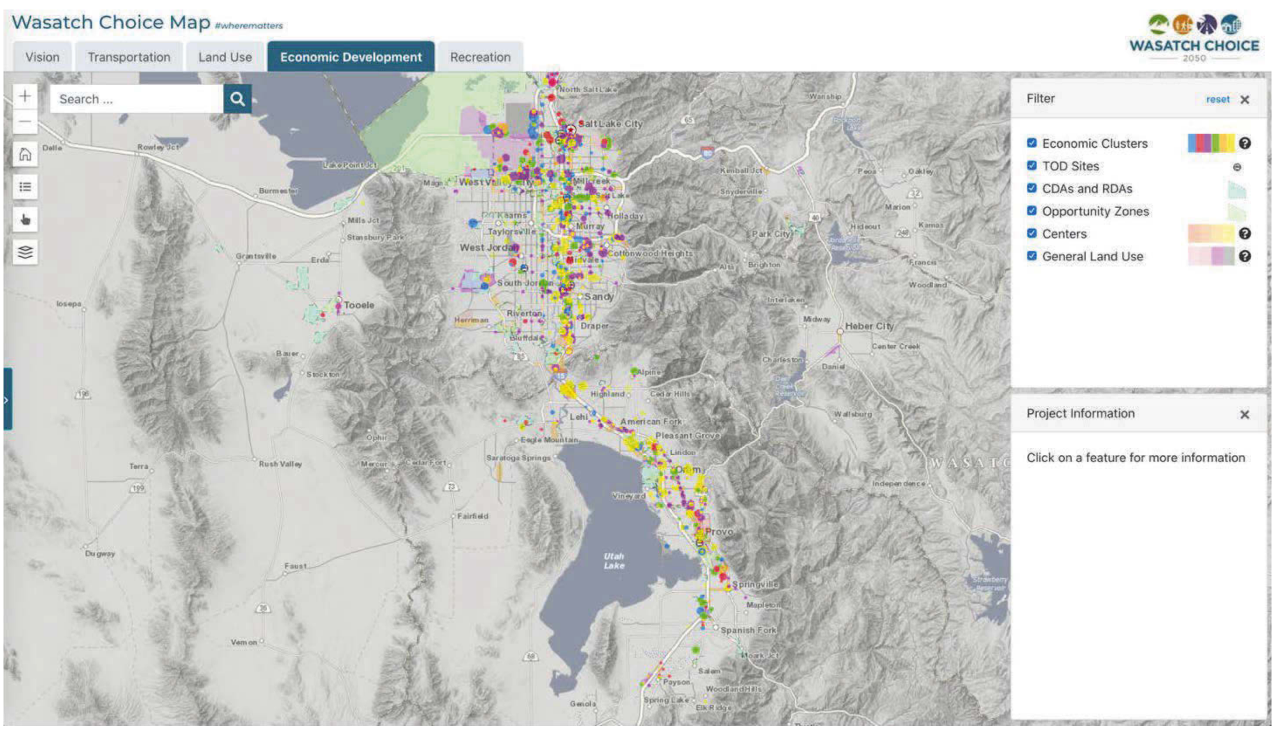


Urban centers are the focus of commerce and local government services benefiting a market area of a few hundred thousand people. Urban centers will be served by high-capacity transit and major streets. They are characterized by two- to four-story employment and housing options.

Town Center — 10 to 50 Housing Units per Acre

Town centers provide localized services to tens of thousands of people within a two- to three-mile radius. One- to three-story buildings for employment and housing are characteristic.

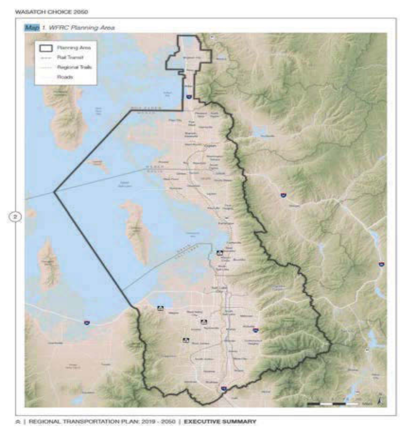
Exhibit 91 Wasatch Choice for 2050 Economic Development Vision



Major Metro Area Players

MPOs: The Wasatch Front has two MPOs, the Wasatch Front Regional Council (WFRC) and the Mountainland Association of Governments (MAG), and a small MPO for the Logan Area (Cache MPO). [145] WFRC is the largest, with boundaries including Salt Lake, Davis, Weber and portions of Box Elder Counties and shown in **Exhibit 94**. The current population of the WFRC is approximately 1.7 million people. MAG's area (Exhibit 95) shares its northern border with WFRC and has a population of 624,000, for a combined population of just over 2.3 million, or 77% of the statewide total.

Exhibit 92 WFRC Planner Area



Modal Agencies: The Utah Transit Authority (UTA) is the Wasatch Front's only transit provider.[146] Its service area covers both MPOs with an area of 1,400 square miles. UTA's service area is comprised of 77 municipalities and serves 80% of the state's population. UTA operates four light rail lines in Salt Lake County, a commuter rail line that operates between Ogden and Salt Lake and between Salt Lake and Provo, and the agency operates over 400 buses and over 400 vanpool vans. The total average weekday boardings are approximately 154,000.

The Utah Department of Transportation[147] ***(UDOT):*** Within the last three years, UDOT has been given a broad directive to improve the quality of life for Utah residents, which includes Good Health, Better Mobility, Strong Economy and Connected Communities as defining themes. The agency's three strategic goals include Zero Fatalities, Optimize Mobility and Preserve Infrastructure. UDOT's operational structure includes four geographic regions, see **Exhibit 96**, and the Department operates over 49,000 lane miles, 1, 941 bridges, and operates over 520 snowplows.

Exhibit 93 MAG Planning Area

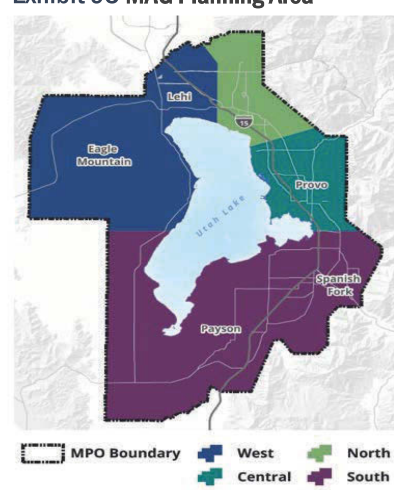
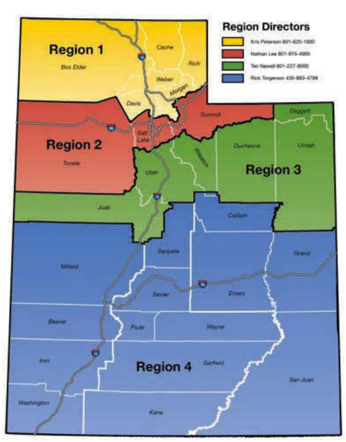


Exhibit 94 UDOT Regions



In terms of funding, Utah is unique. The majority of UDOT's capacity projects are funded with state general fund monies (17% of state sales taxes, designated as auto-related) through a fund called the Transportation Investment Fund (TIF). Annually, TIF contributions are approximately $750 million. Operations, maintenance and preservation are largely are funded with gas taxes. Utah raised its gas taxes in 2016 and indexed the increase to fuel rack rates. This gas tax fund is called the Transportation Fund and generates approximately $400 million annually. UDOT receives about $305 million in federal funding, which is used almost exclusively for preservation activities. For every dollar spent in Utah, approximately $.73 is state funding and $.27 is federal.

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145 "Wasatch Front Regional Council (WFRC): Association of Governments," Wasatch Front Regional Council, accessed October 26, 2021, https://wfrc.org/; "Welcome to Mag," Home | MAG, accessed October 26, 2021, https://www.mountainland.org/.

146 UTA, accessed October 26, 2021, https://www.rideuta.com/.

147 UDOT, accessed October 26, 2021, https://www.udot.utah.gov/main/f?p=100%3A6%3A0%3A%3A%3A%3AV%2CT%3A%2C1.

Freight: There are seven freight railroads operating in Utah and one major freight intermodal center in Salt Lake County, adjacent to I-80, I-215 and about 5 miles west of I-15. The facility is also located within 2 miles of the Salt Lake International Airport and adjacent to a hoped-for inland port center. Union Pacific is the dominant Class 1 railroad, but BNSF operates in the state by trackage rights. The state's freight network includes over 2,000 miles of freight-designated roadways, over 1,300 miles of freight rail lines, five oil refineries, and approximately 5,000 miles of pipeline. Top commodities by value include base materials, electronics, machinery, manufacturing, vehicles, foodstuffs and pharmaceuticals.

Utah Unified Transportation Plan[148]*:* UDOT, UTA and the state's four MPOs (WFRC, MAG, Cache MPO, and Dixie MPO) work cooperatively to develop the Utah Unified Transportation Plan (UP) every four years. The agencies have established a Joint Policy Advisory Committee (JPAC) whose sitting members include the Executive Directors and key staff from the six agencies as well members from the governing bodies of the six agencies. Underneath JPAC sits the Unified Plan committee, which has six subcommittees including **Exhibit 97**. The agencies use joint financial assumptions and have developed a joint financial model, MAG and WFRC use a joint travel demand model along the Wasatch Front.

Exhibit 95 **JPA/UP Committee Structure**

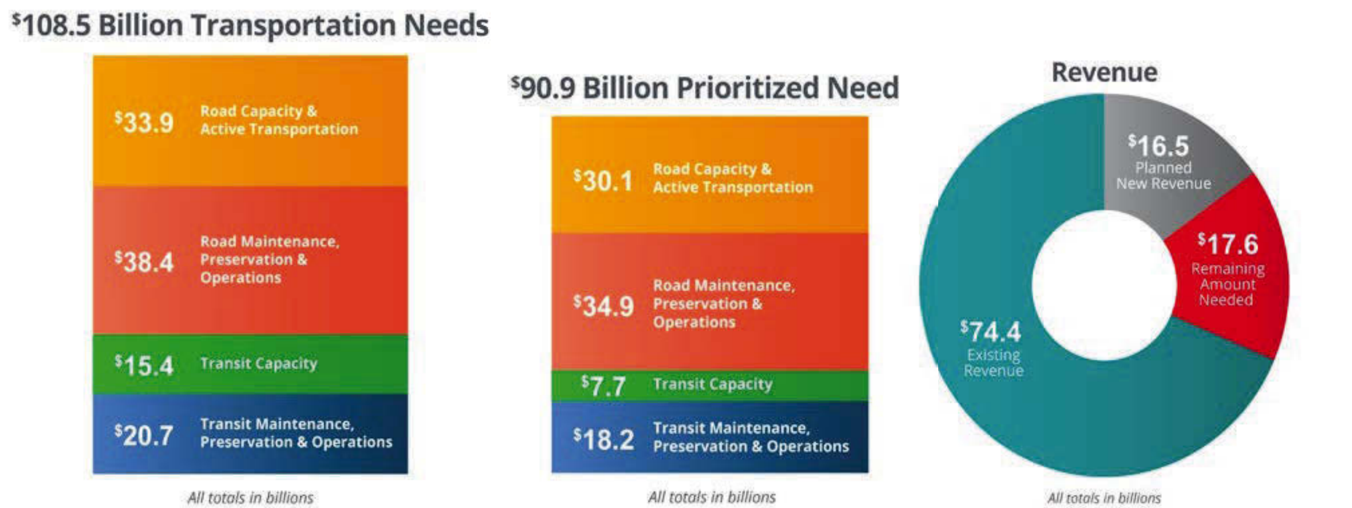
Underpinning the UP are four statewide initiatives: good health, better mobility, strong economy and connected communities, see **Exhibit 100**. Interestingly, UDOT is one of only a few states that produce a project-based long-range transportation plan that is phased and financially constrained. Not only does this more readily allow the inclusion of the statewide plan in the UP, but it also helps the partners establish overall transportation needs in the state, see **Exhibit 98**. This has been an important tool in messaging the need for state and local funding. Currently, UDOT receives approximately 17% of all state sales taxes to fund its capacity program. This accounts for about $750M in annual contributions. In the last two years, the state has allowed transit capacity and active transportation projects to be funded with the state TIF Fund. UDOT funds its preservation needs with state gas taxes and with its federal contributions. Utah has fully funded its roadway preservation needs and indexed its state gas tax to the rack-rate of fuel, establishing a floor to prevent fuel price deflation.

Locally, the Utah Transit Authority receives approximately $280M in local option sales taxes, which is over half of the agency's 2018 operating budget of $403.1M. The Utah Legislature has also authorized additional

[148] "Home," Utah Unified Transportation Plan, January 29, 2021, https://unifiedplan.org/.

sales tax adjustments for transit and local road preservation and capacity projects; however, these increases must be passed by local governments.

Exhibit 96 **Utah Transportation Need & Funding**

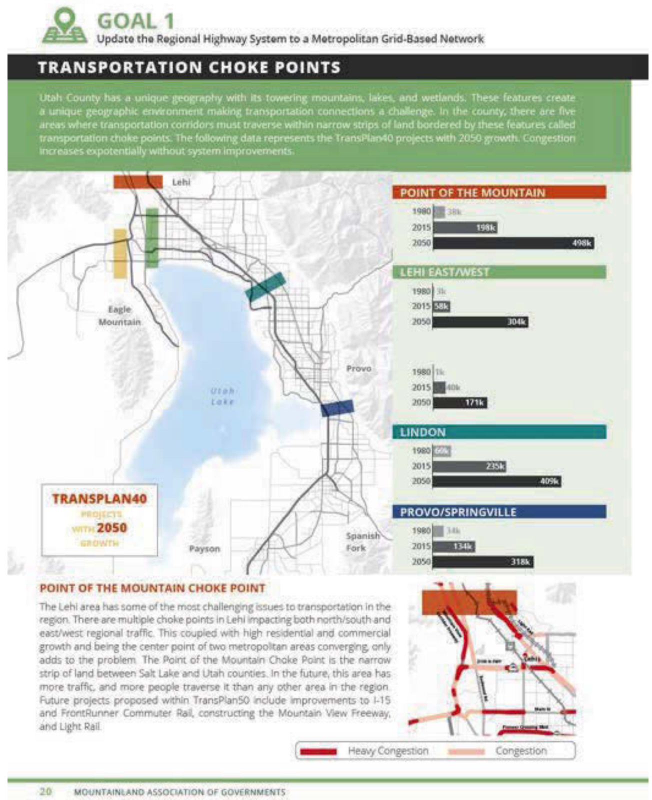


Definitions of corridors and characteristics

WFRC: The 2019-2050 RTP does not specifically define corridors but addresses corridors, and corridor planning extensively in their document. The RTP does address the CanaMex corridor and the geographic location of the region and the intersection of I-15 and I-80 as the crossroads of the west, acknowledging the region's importance to national security, and the economic vitality of the region and western US. The RTP also recognizes the difficulty the mountainous topography of the region has on limiting the number of ingress and egress points to the region. This does suggest WFRC considers corridors broadly. Generally, the WFRC RTP addresses corridors in terms of facilities, either roadway or transit. While there is extensive consideration for how local objectives are influenced by congestion and reliability on I-15, there is very limited consideration of how national interests are affected.

MAG: Similar to WFRC's RTP, MAG's 2050 RTP does not formally define corridors, but it does speak broadly about the need for east/west corridors and the role of choke points in limiting transportation options, see **Exhibit 99**. Generally, Mag's RTP, like WRFC's speaks of corridors as facilities but does recognize the value that a comprehensive grid system can have on system-level functionality. MAG's plan also demonstrates a comprehensive understanding of the relationship between corridors and development patterns. The concept of <u>accessibility</u> as a performance measure underpins both MAG's and WFRC's plans. Household access to jobs, business access to workers, freight access, active transportation and transit access. All are emphasized over more traditional mobility measures such as speed of travel.

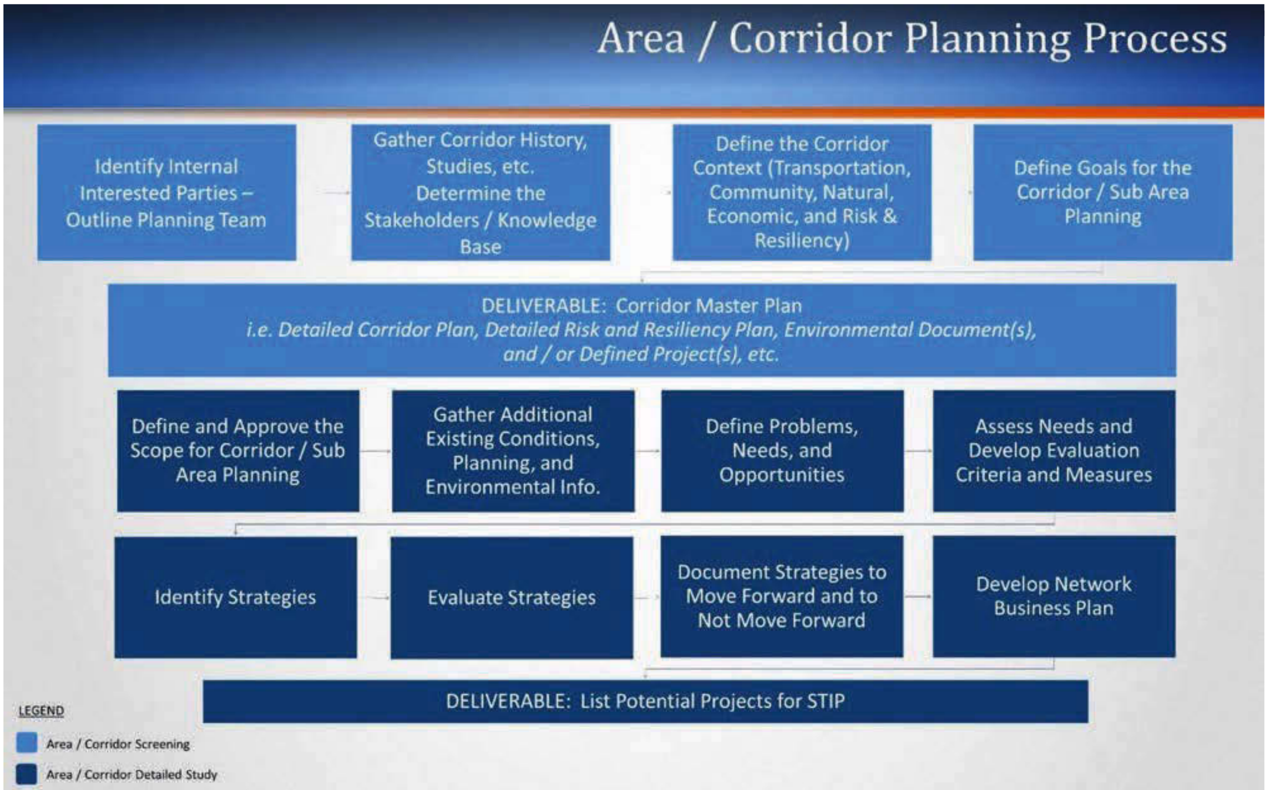
Exhibit 97 MAG Corridor Choke Points



UDOT: UDOT has developed a contextual-based intermediate/corridor planning framework called the "Solutions Development Process."[149] There are two components to the framework: corridor/area screening and corridor planning, see **Exhibit 101**. The framework does not arbitrarily define corridors. Corridors are defined contextually, meaning they can be defined by facility, area or systemically depending on the nature of the problem statement. The framework's screening component reviews each corridor/area by <u>six contexts: transportation, economic, natural, risk and resilience, health and community</u>. By using a contextual approach, the framework's screening process guides the establishment of a comprehensive understanding of how transportation corridors should function to improve the multifaceted goals and objectives developed by stakeholders. The basic premise of the framework is that multifaceted goals and objectives will lead to the development of transportation corridor goals, objectives and evaluation criteria/performance measures that reflect a broad understanding and therefore lead to improved outcomes. Importantly, the performance measures are used in subsequent alternatives analyses to develop a comprehensive solution for the corridor.

149 Corridor planning, accessed October 26, 2021, http://maps.udot.utah.gov/wadocuments/Apps/planning/.

Exhibit 99 **UDOT Intermediate/Corridor Planning Framework**



Corridor Management Strategies

MPOs: WFRC and MAG do not specifically define corridor management in their respective plans. In cooperation with UDOT, they are using national and local performance measures in the development of their plans. Generally, both MPOs think about corridors from a broad perspective and employ a multi-faceted approach in the respective plans. Specific regional strategies intended to achieve the goals of the transportation system include land-use efficiency, travel demand management, active transportation use, connectivity, grid spacing, accessibility, and a focus on transit. Both MPOs consider land-use as a primary component in managing future travel demand. However, they approach it from different perspectives.

WFRC is very aggressive in advocating future land-use changes as a means of managing system and corridor level travel demand, specifically SOV use. A core element of WFRC's travel demand projections is a land-use plan based on 7D Activity Centers and Livable Corridors. Their concept of activity center development focuses on increasing density, diversifying uses, minimizing the distance to transit, and other D's as well. They also recognize industry and freight clusters but have not focused on what 7D's could mean for industrial contexts.

Envision Utah and Transit/Land-use Paradigm Shifts

In the late 1990s, a non-profit organization named "Envision Utah" led a vast public education and participation effort, engaging thousands of Wasatch Front residents and elected officials in an effort to develop different growth scenarios and evaluate not just the transportation effects, but also effects on water consumption, farmland/open space consumption, air quality, lifecycle infrastructure costs, and other measures. Through the process, people were given “playing chips” that represented different development styles and densities. They were to find locations for the next million residents. Most groups started with low-density chips and discovered their most valued farmlands and open space would be consumed quickly. At this point, most groups reversed course. They used fewer low-density suburban chips, and many more high-density mixed-use chips placed mainly amidst existing commercial centers and corridors, leaving single-family neighborhoods essentially untouched.

Results were aggregated into Traffic Analysis Zones and tested in the regional model as “Trendline” vs. “Centers and Boulevards.” The Centers and Boulevards concept had considerably better performance in most of the measures. Given that neither UDOT nor the MPOs had land-use authority, it fell to each of 77 municipalities to modify their general plans to better encourage this type of development. Though it has taken two decades, many of those communities have adopted form-based codes, eliminated parking minimums in key areas, and elevated the calls for Complete Street development. The general call for premium transit has been strong, and the Wasatch Front now has more premium transit per capita than most cities that are much larger. Some of this paradigm shift has been a function of a general national shift toward Complete Streets walkable Activity Centers. But certainly, Envision Utah and consistent efforts of the MPOs have also played a strong role.

WFRC’s Transportation/Land-use Connection Program

WFRC’s policy board made up of local elected officials as well as UDOT and UTA executives, formally adopts the 2050 land-use vision. As noted, more and more communities are modifying their zoning and regulations to encourage 7-D development patterns, and the transportation and land-use community is increasingly likely to have heard of the 7D’s or all of the components (if not labeled as “the 7-Ds”). The shift in community desire to convert auto-oriented urban corridors into walkable boulevards that can catalyze 7-D development is challenging for UDOT, as they have long been attuned to delivering standardized products where auto-based measures of effectiveness have been dominant. But UDOT is increasingly responsive to community desires and alternative measures such as economic impact measures.

To motivate local governments to take actions that support the regional land-use vision, WFRC initiated its Transportation and Land Connections program in 2014.[150] As of 2020, the program receives about $1.5 million annually, to which local governments contribute another $0.3 million in matching funds if selected for a project. The typical project is about $100,000, resulting in 18-20 projects per year. Local governments apply for TLC program funding, and a core element of selecting applicants is how their proposed projects support and implement elements of the 2050 land plan. Typical projects include developing form-based codes, creating small area plans for mixed-use development, and multimodal corridor studies. Beyond WFRC, funding partners include Salt Lake County, UDOT and UTA. See Error! Reference source not found. for a graphic of current and past studies by location and project type.

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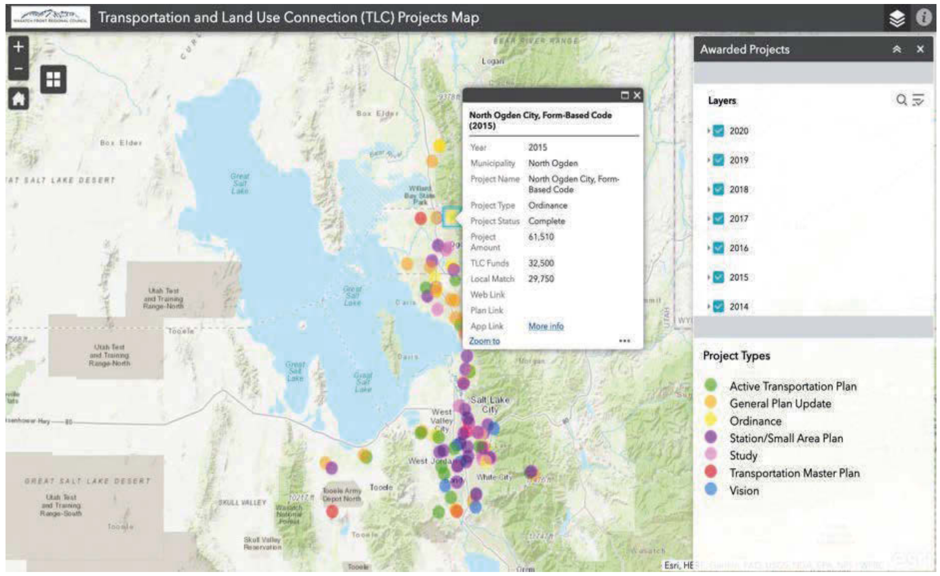
[150] “Transportation and Land Use Connection,” Wasatch Front Regional Council, accessed October 26, 2021, https://wfrc.org/programs/transportation-land-use-connection/.

MAG is less aggressive, preferring a bottom-up approach where local governments drive land-use planning. When current land-use plans cannot accommodate projected population and employment growth, MAG staff work with their local government partners to allocate the unaccommodated growth through increased densities. MAG is a partner in the Wasatch Choice for 2050 program and actively works with their local government partners to educate them on the effect land-use has on travel demand, infrastructure needs, air quality and life cycle costs and generally the trade-offs of difference develop patterns.

Exhibit 100 TLC Studies



Managed Motorways: Both MAG and WFRC assume have adopted an ambitious freeway management program in their regional plans known as "Managed Motorways" or "Managed Freeways." The concept is to use mainline volume and speed detectors to sense when the freeway is nearing failure, then automatically increase the wait time at on-ramps so that the system will not collapse. The system is similar to one implemented in Victoria, Australia. In the United States, Denver and Salt Lake have been the first to entertain it. The program looked like it had good support at UDOT initially, but it appears to have lost momentum. Denver appears to be moving forward.

UDOT: UDOT's current corridor management system is robust, but primarily focused on traditional transportation performance metrics like speed, reliability and delay. Its previous project prioritization process/model was also heavily weighted with those measures, plus existing and future volumes. This resulted is a bias toward traditional capacity projects on freeways and arterials in the urbanized areas of the Wasatch Front. UDOT's previous capacity project prioritization process/model was also focused on existing issues and did not directly consider future outcomes. In a recent update to their capacity project prioritization process/model, UDOT has made a conscious decision to move away from sole reliance on traditional metrics and focus instead on future outcomes rather than just

Exhibit 101 UDOT Prioritization Categories

current issues. **Exhibit 103** shows the primary prioritization categories and the measures used in the updated process/model.

At an operational level, UDOT has made considerable progress in optimizing an arterial system. UDOT has implemented an innovative traffic signal optimization program that uses real-time traffic data to assess how vehicle platoons travel through a given corridor, using an "arrival on red analysis," as a means to optimize signal timing. It has been a huge success, and it allows the Department to increase vehicle/person throughput through the corridor, thereby increasing its capacity, without major capital investments. UDOT is also unique in that it has real-time control over 90% of traffic signals in the State of Utah; this includes local government signals. UDOT works with its local government partners, some of whom have their own sophisticated operations program, in the optimization of the local signal systems. At the same time, UDOT is parting with UTA in a pilot project to improve bus reliability and travel times in corridors using a Direct Short-Range Communication system (DSRC). The wayside communication system tracks buses within corridors and communicates with the signal system to give additional green time or shorten red cycles if buses fall behind on their schedule.

In addition to the above, UDOT makes extensive use of ITS technology, including vehicle sensing on freeway on- and off-ramps, ramp metering, VMS, traffic cameras, real-time tracking of snowplows, weather sensors, and an extensive fiber-optic network communication backbone to manage its corridors. UDOT's ITS architecture is developed in cooperation with WFRC, MAG and local governments.[151] The joint ITS architecture concept plan includes consideration of data systems, commercial vehicle operations, electronic toll collection, emergency management, freeway management, incident management, parking management, surface street management, transit systems, and traveler information elements.

UDOT Intersection Control Evaluation Program

Alternative Intersections are high-efficiency designs that both reduce congestion and generally improve safety relative to more traditional, "double left turn" designs. While Utah was one of the early pioneers of Alternative Intersections, Florida was perhaps the first state to formalize a process for requiring that all at-grade intersections be evaluated against all possible design concepts when there is significant work proposed on a corridor.

Large arterial intersects tend to have 4-phase signals (i.e., left turn phases, and sometimes "double left" turn lanes), but these get very congested and dangerous. When roundabouts became popular, Florida started requiring that roundabouts also be investigated. As more intersection designs become popular, Florida formalized its ICE program but required that all known design options at least be screened quickly for potential feasibility. If reasonably feasible, then the various options should be advanced for further analysis against a multivariate criterion. The design that appears to provide the best value relative to objectives for the corridor would then be selected. Many states are quickly adopting this program, and Utah is among them. Several alternative intersection designs are highly compatible with walkable mixed-use urban corridors. ICE programs offer significant potential for helping corridor management activities better integrate with community economic development objectives.

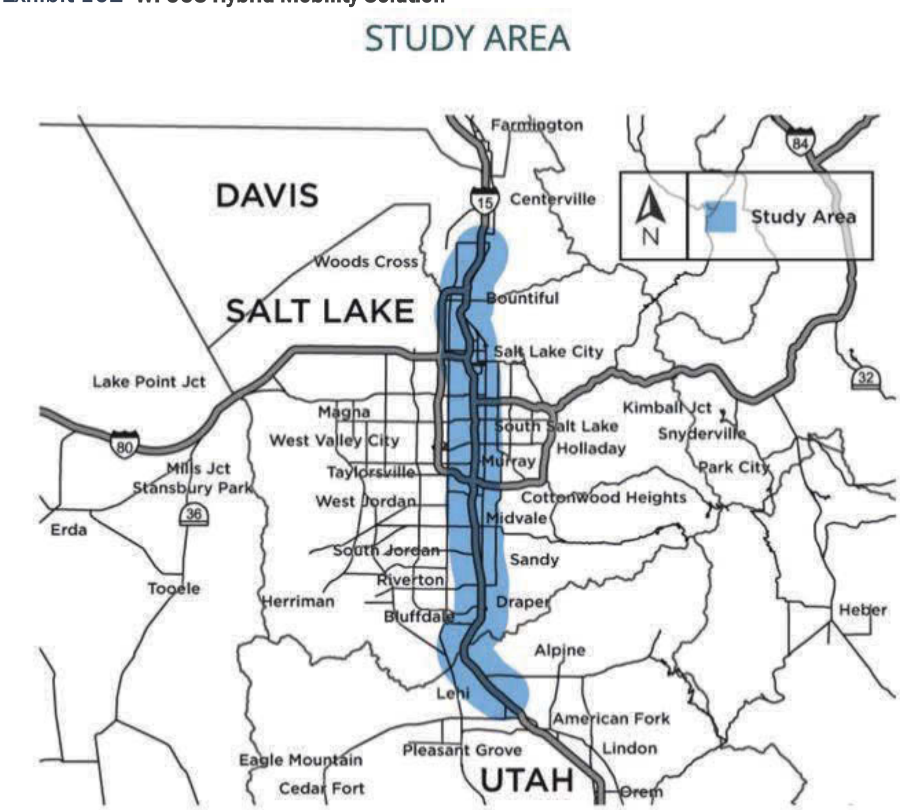
[151] UDOT, accessed October 26, 2021, https://www.udot.utah.gov/main/f?p=100%3Apg%3A0%3A%3A%3A1%3AT%2CV%3A5333%2C.

Wasatch Front Central Corridor Study (WFCCS)[152]

UDOT, MAG, WFRC and UTA completed a groundbreaking analysis of the I-15 corridor in 2017, see **Exhibit 104** for the study area. The unique aspect of the WFCCS included its management and decision-making structure, baseline assumptions, and analysis framework. The study was managed by a UDOT project manager, but with agreement from the executive leadership of each organization, that the project manager (PM) reported to a management committee comprised of senior management staff from each participating agency; the PM did not represent UDOT, rather the PM represented each of the agencies. The PM managed the consultant team but took direction from the agency management committee.

The agencies agreed on a key baseline assumption that all solutions were on the table, and there were no predetermined outcomes. Additionally, the UDOT project team developed a broad set of contextually based corridor goals, objectives and performance measures that would underpin the alternatives analysis; these were subsequently approved by the executive leadership of each agency. The corridor goals included system safety, increase system throughput, improve travel time, increase accessibility to jobs and education, improve air quality, improve economic outcomes, reduce transportation household costs, and improve mode balance.

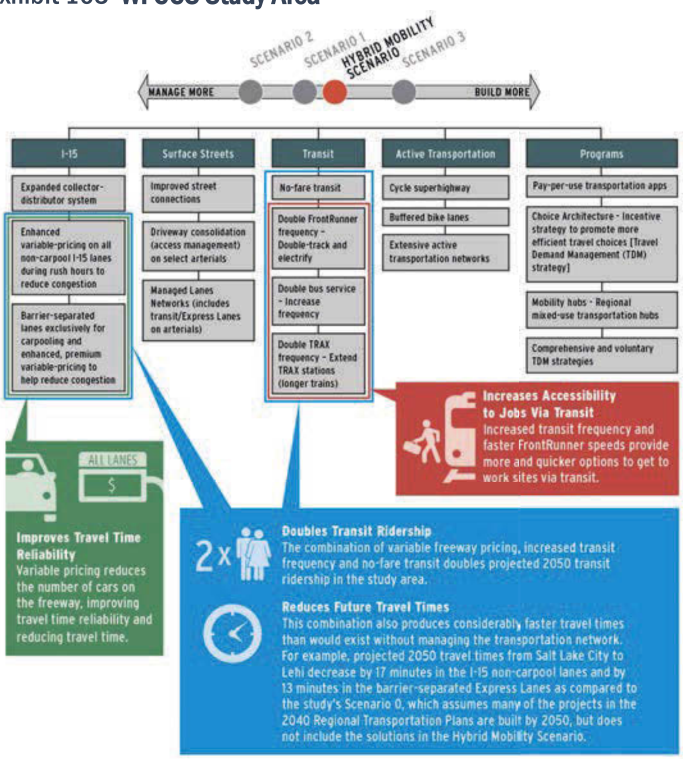
Exhibit 102 **WFCCS Hybrid Mobility Solution**



152 "Final Report Summary," Wasatch Front Central Corridor Study, accessed October 26, 2021, http://wfccstudy.org/.

The WFCCS analysis evaluated three corridor investment packages that ranged from demand-centric to supply-centric strategies. The team's approach focused on providing policymakers with a trade-off analysis of the different investment strategies so they could make an informed decision about which strategy fit the region's transportation, land-use and quality of life objectives. The WFCCS Team did develop a Hybrid Mobility Solution (HMS); see **Exhibit 105** above, which drew upon the highest perform elements of each strategy, but again it was only developed for comparison purposes. Policymakers adopted the HMS, the elements of which were included in the 2019-2050 Utah Unified Plan. Significantly, the HMS included pricing strategies. This was a significant step forward in how policymakers began to accept non-traditional strategies. Another core element of the study was its focus on developing a comprehensive multi-part solution for the corridor. As can be seen in **Exhibit 106**, elements of the HMS included programs, active transportation, transit, surface street and freeway improvements. Importantly, the solution set also included policy proposals like congestion pricing and no, or low fare transit. When those pricing policies were combined with a doubling of bus service and significant improvements in commuter rail and light rail service in the corridor, there was a doubling of transit usage and shift of vehicle demand to the edges of the peak period. Agency partners have adopted this solution set approach as they evaluate other corridors.

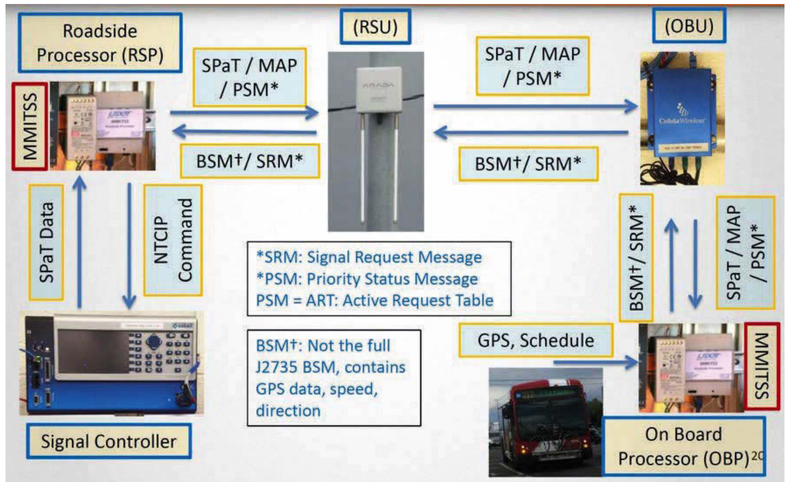
Exhibit 103 WFCCS Study Area



Incorporation of Advanced Technologies- ACES "issues"

As mentioned above, UDOT in cooperation with UTA is piloting a DSRC based connected vehicle technology in an 11-mile section of Redwood Rd in Salt Lake County, see **Exhibit 106** for the system architecture. UTA also operates a light rail line in UDOT's 400 South corridor, in Salt Lake City, and a BRT line in UDOT's University Ave in Provo and Orem Cities, in Utah County. While the 400 South and University Ave corridors are not employing DRC, UDOT has integrated the operation of the systems with its traffic signals and provides signal priority for the transit vehicles.

Exhibit 104 UDOT/UTA Connected Vehicle Architecture



The UDOT has a Technology and Innovation Engineer position in its Traffic Management Division who is tasked with readying the Department for the eventual adoption of advanced "Automated, Connected, Electric, Shared" (ACES) technologies. The Department is a part of a public-private coalition exploring V2I, V2V and V2X applications, exploring contractual relationships, and organization structures for the use of data in corridor operations. At the same time, UDOT's Planning Division is working with AASHTO, FHWA, and their MPO partners in developing a long-range transportation planning framework that accounts for the adoption of ACES technologies on future travel demand and needed infrastructure improvements.

The State of Utah has enacted five bills related to ACES:[153]

- HB 373 enacted in 2015 authorizes UDOT to conduct a connected vehicle technology testing program.
- HB 280 enacted in 2016 requires a study related to autonomous vehicles, including evaluating NHTSA and AAMVA standards and best practices, evaluating appropriate safety features and regulatory strategies and developing recommendations.
- SB 56 enacted in 2018 amended HB 373 of 2015 (see above) to define a "connected platooning system" to mean a system that uses vehicle-to-vehicle communication to electronically coordinate the speed and braking of a lead vehicle with the speed and braking of one or more following vehicles.
- SB 72 enacted in 2019 defines "connected vehicle" and allows UDOT for roadway operation purposes, to obtain, collect, and utilize anonymized location data of a connected vehicle.
- HB 101 enacted in 2019 Defines key terms related to autonomous vehicles. Requires a vehicle equipped with an automated driving system (ADS) to be properly titled, registered, and insured.

[153] Gretchenn Dubois Douglas Shinkle, "Autonomous Vehicles: Self-Driving Vehicles Enacted Legislation," Autonomous Vehicles | Self-Driving Vehicles Enacted Legislation, February 18, 2020, https://www.ncsl.org/research/transportation/autonomous-vehicles-self-driving-vehicles-enacted-legislation.aspx.

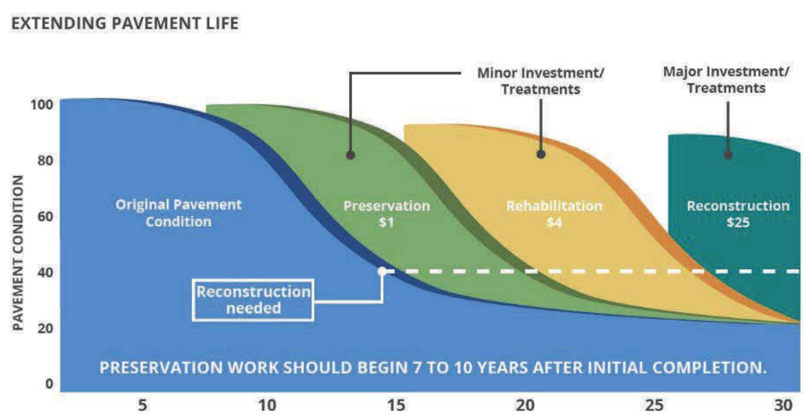
Methodologies to Assess the Effectiveness of Strategies

UDOT has a robust system for assessing and managing its arterials and freeways. However, the methods and measurements currently focus on traditional strategies related to congestion, decreasing travel times and improving travel-time reliability. Like a lot of DOTs, UDOT has a Traffic Management Division that is charged with monitoring, evaluating, and developing new methods and measures to improve the operations of its transportation network. UDOT has an extensive ITS program with a statewide system of traffic cameras, VMS signs and weather sensors.[154] To communicate with this ITS system, UDOT has installed a fiber network that covers a significant portion of its transportation network.[155] As mentioned earlier, the ITS Architecture in the urbanized areas is jointly developed with its MPO partners.

UDOT monitors its freeway system along the Wasatch Front using in-pavement sensors, cameras, and blue tooth and probe sensors. UDOT also operates the longest continuous high occupancy/toll express lane system in the US along its Wasatch Front, I-15 corridor.[156] UDOT has implemented variable toll rates along the corridor and sells a limited number of toll passes. The number of toll passes is adjusted to maintain lane speeds at 50-55 mph. Toll values are capped at $2.00. Prior to September 30, 2019, UDOT allowed hybrid vehicles in the express lanes for free. UDOT also has employed an extension ramp metering program along the Wasatch front and is evaluating dynamic metering as part of a larger corridor management strategy called Managed Motorways, as mentioned above.

UDOT has also made considerable efforts to assess the life cycle costs of its facilities and currently has the resources to preserve its system. UDOT has adopted a "good roads cost less" strategy for its system and invests in early preservation activities to reduce the long-term life cycle costs of its facilities, **see Exhibit 107**.

Exhibit 105 **UDOT Good Roads Cost Less**



UDOT's measuring and monitoring system is still largely focused on the traditional transportation metrics of congestion, delay and reliability; it is still largely problem-focused. Currently, there is a disconnect between planning goals, objectives. and performance measures. However, UDOT and its partners are making considerable efforts to close that gap. Two efforts in particular merit mentioning; 1) **UDOT has developed a new project prioritization model that reflects economics, land-use, accessibility, and quality of life metrics in addition to the more traditional metrics**, and 2) the Department has implemented a significant workflow change in the adoption of Solutions Development Process. As mentioned above, the planning framework is contextually

154 "Udot Traffic," UDOT TRAFFIC, accessed October 26, 2021, http://udottraffic.utah.gov/.

155 "UDOT Fiber," ArcGIS web application, accessed October 26, 2021, https://horrocks.maps.arcgis.com/apps/webappviewer/index.html?id=096d0a7dd31a4be289b9623935308fc9.

156 "Express Lanes," UDOT, accessed October 26, 2021, https://www.udot.utah.gov/expresslanes/.

based, meaning it considers land-use/community, economic, resilience, natural, transportation, health factors at the outset of the process.

In this way, contextually based transportation goals, objectives and, importantly, evaluation criteria/performance measures are developed to evaluate alternatives in the subsequent phase of the process. In this way, UDOT and its partners jointly establish the process by which the corridor is developed and managed in the future. It is also important to note that **UDOT, UTA and their MPO partners recognize that corridor improvements require a "solution set" approach, which considers policy measures like pricing, transit and roadway capacity, active transportation, travel demand management and operational improvements**. To measure the efficacy of proposed solutions, UDOT is developing real-time performance monitoring. As such, UDOT and its partners have made, and continue to make considerable investments in data sources and applications, which will improve how they measure corridor performance and close the gap between planning objectives and performance measurement.

Data sufficiency and validity

UDOT has made considerable investments over the last ten to fifteen years to improve its data sources. UDOT Operations maintains both live and historical traffic data statewide. Point data is collected through radar and loops and can be accessed through its Freeway iPeMS web page; iPeMS provides point data for speeds and volumes and is publicly available.[157] UDOT's PeMS data is probe data that variably samples traffic flows and provides speed and travel time information; data is collected for each functional class down to the minor collector statewide. This data is available to anyone working on UDOT projects as well the Department's MPO partners. **Exhibit 108** provides a summary of UDOT's traffic data types and applications.

UDOT also maintains a Freeway Performance Web Site where users can view recent, but historical, travel times and speed data.[158] The Department uses the data to develop various tools including mobility cakes, which measures delay caused by various causes; freeway delay, freeway reliability, and incident occurrences.

UDOT has purchased data from HERE. This data provides travel-time information for Utah highways. HERE travel-time estimates are primarily derived from GPS data obtained from in-vehicle navigation devices and represents approximately 2% of the Utah vehicle fleet. UDOT is currently evaluating how the travel-time estimates from HERE compare to another source of travel-time data, obtained from the Google Directions Application Program Interface (API). The source of this travel-time information is from users of Google Maps directions who, by virtue of using the direction service, agree to provide Google with their geographic position. Google aggregates this data to produce travel-time estimates for highway segments. UDOT is also evaluating overall organizational data workflows and has developed a Data Portal and UPLAN for sharing and accessing data, both internally and with its partner agencies.[159]

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[157] "Performance Measurement System (PeMS)," UDOT, accessed October 28, 2021, https://udot.iteris-pems.com/#40.750557,-111.762199,12.

[158] "Freeway Performance Metrics," Freeway Performance Metrics Home Page, accessed October 26, 2021, http://udottraffic.utah.gov/FreewayPerformanceMetrics/Home.aspx.

[159] "UDOT Open Data," UDOT Open Data, accessed October 26, 2021, http://data-uplan.opendata.arcgis.com/; "Welcome to UPlan," Uplan.maps.arcgis.com, accessed October 26, 2021, https://uplan.maps.arcgis.com/home/index.html.

Exhibit 106 Summary of UDOT Data and Applications

UDOT Keeping Utah Moving

TRAFFIC DATA AND APPLICATIONS

UDOT uses radar, loops, bluetooth and probe samples to collect traffic data. This document describes these data sources and current applications.

BLUETOOTH

Requirements:
- Sensors in the field
- Data must be purchased from third party
- Bluetooth/Wi-Fi must be activated

Benefits:
- Higher penetration rate
- Can be installed for specific projects
- Collects travel time & origin-destination

Description:
- Data is collected at Point A and Point B only

Limitations:
- Cannot measure volume
- Travel time updates lag behind real-time
- Parallel corridors are hard to differentiate (I-15 and frontage roads)

PROBE

Requirements:
- Vehicle navigation system or app activated
- Data must be purchased from third party

Benefits:
- Does not require field equipment
- Collects speed and travel times

Description:
- Data is collected at multiple points along vehicle path

Limitations:
- Lower penetration rate
- Cannot measure volume or determine origin/ destination
- Travel times are unreliable for low volume roads and mountainous geography

POINT

Requirements:
- Radar or loop equipment in the field

Benefits:
- Collects volumes and speed
- Data does not need to be purchased from third party

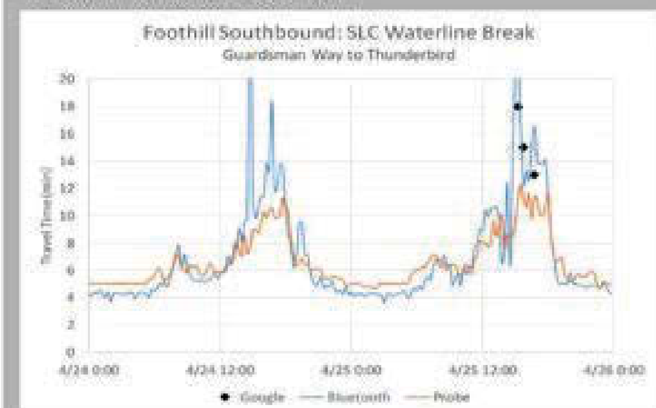
Description:
- Data is collected at equipment location
- Available on major highways in urbanized areas

Limitations:
- Can only collect data at equipment locations
- Can not collect travel times or origin-destination

Example of Google, Bluetooth, and Probe data for the same route

⇒ Probe travel time may be less reliable with fewer samples

⇒ Bluetooth may collect data for adjacent routes



Applications	Bluetooth	Probe	Point
Advocate for Funding		•	•
Evaluate Project Improvements		•	•
Manage Traffic During Construction	•	•	
Describe Events and Incidents		•	
Traffic Forecasting (Video Recording)		•	•
Identify Choke Points		•	•
Identify Construction Windows			•
Origin/Destination	•		
Provide Alerts During Construction	•	o	
Executive Speed Reports		•	•
Historical Data for Corridors		•	•
Special/Short Term Deployment	•		
VMS Display Travel Times	•	o	

Bluetooth Probe Point o In Development

2019 HERE Data Validation Study performed by RSG: 95% of routes studied were not significantly different from Google data

Sample Size Comparison

Bluetooth	20-40% of vehicles
Point	100% of vehicles
Probe	2-15% of vehicles

Date Modified:
May 10,2019

Wasatch Front Region Takeaways

- WFRC and MAG do not specifically define corridor management in their respective plans.
- Within the last three years, UDOT has been given a broad directive to improve quality of life for Utah residents, which includes Good Health, Better Mobility, Strong Economy and Connected Communities as defining themes
- UDOT, UTA and the state's four MPOs (WFRC, MAG, Cache MPO, and Dixie MPO) work cooperatively to develop the Utah Unified Transportation Plan (UP) every four years.
- Underpinning the UP are four statewide initiatives: good health, better mobility, strong economy and connected communities
- UDOT's capacity project prioritization process/model, UDOT has made a conscious decision to move away from sole reliance on traditional metrics and focus instead on future outcomes rather than just current issues.
- UDOT has developed a contextual based intermediate/corridor planning framework called the "Solutions Development Process
- UDOT has a robust system for assessing and managing its arterials and freeways. However, the methods and measurements currently focus on traditional strategies related to congestion, decreasing travel times and improving travel-time reliability. At an operational level, UDOT has made considerable progress in optimizing its arterial system. UDOT has implemented an innovative traffic signal optimization program that uses real-time traffic data to assess how vehicle platoons travel through a given corridor, using an "arrival on red analysis," as a means to optimize signal timing.
- UDOT has made considerable investments over the last ten to fifteen years to improve its data sources. UDOT Operations maintains both live and historical traffic data statewide. Point data is collected through radar and loops and can be accessed through its Freeway iPeMS web page; iPeMS provides point data for speeds and volumes and is publicly available.[160]

UDOT in cooperation with UTA is piloting a DSRC based connected vehicle technology in an 11-mile section of Redwood Rd, in Salt Lake County

[160] "Performance Measurement System (PeMS)," UDOT, accessed October 28, 2021, https://udot.iteris-pems.com/#40.750557,-111.762199,12.

3.7.6 Corridor "Stop" #3: Utah County Corridor Choke Points

Historically, Utah County has developed town by town with little thought to inter-regional transportation networks, see Exhibit 109. This has led to a patchwork of local transportation network facilities and an over-reliance on UDOT facilities. There just isn't a strong arterial and collector background network of non-UDOT transportation facilities. Local facilities have largely been built as part of land-use development projects. As such, these facilities are focused on serving individual residential and commercial developments, with little consideration of regional travel needs. MAG has recognized this issue for some time has focused their transportation long-range plans on the need for a comprehensive connect grid system

As depicted in **Exhibit 110**, MAG is projecting significant transportation network failures in 2050 because of the lack of a comprehensive grid system. Each corridor chokepoint is described below in detail. MAG's TransPlan50 plan is based on the benefits of relieving regional congestion by completing the grid network and the projects listed in their plan focused on that end. With the projected population growth through 2050, overall travel delay in the region increases elevenfold compared to 2018. Their modeling shows that with a connected arterial and collector grid network with no additional freeways, the 2050 travel delay would only grow to seven times that of today. With the addition of the proposed freeways in the plan, congestion rises to only three times the current delay, well within acceptable limits of a metropolitan area of 1.3 million people.

Exhibit 108 MAG Network Choke Points

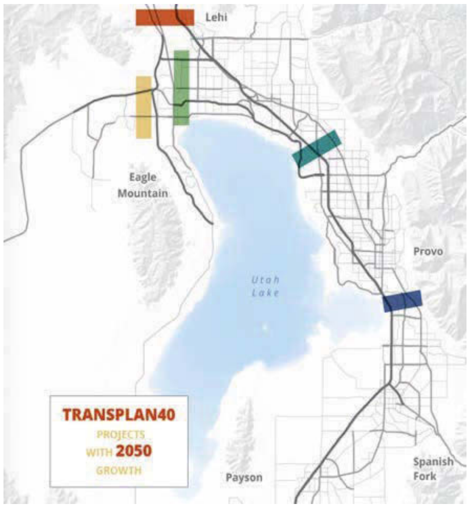


Exhibit 107 Historical Development Patterns

Exhibit 109 Transplan40 Choke Points

CEDAR PASS CHOKE POINT

The narrow connection between Lehi and the Cedar Valley through the mountains create the Cedar Pass Choke Point. The area bordering this choke point is projected to have over 200,000 people by 2050. Because of the limited options for transportation corridors, SR-73 is proposed in the plan to be

Heavy Congestion | Congestion

PROVO/SPRINGVILLE CHOKE POINT

In the future, the area between Provo and Springville becomes the most congested choke point in the county. It currently only has two regional connections, State Street and I-15. There are very limited transportation solutions due to Provo Bay, wetlands, and the Wasatch Mountains.

Future solutions include a parallel freeway over Provo Bay, FrontRunner Commuter Rail, additional lanes on I-15, and light rail.

LINDON CHOKE POINT

The Lindon Choke Point today has the highest traffic volumes in the valley with a significant commuter movement between the central and northern areas of the county. With only three highway corridors, State Street, I-15, and Geneva Road, as well as FrontRunner Commuter Rail, this is an important area to focus on relieving congestion. TransPlan50 proposes improvements to I-15 and commuter rail in this area as well as the addition of light rail and bus rapid transit along State Street.

LEHI EAST/WEST CHOKE POINT

East/west travel through Lehi with its numerous wetlands, the Point of the Mountain to the north and Utah Lake to the south, all limit transportation, creating the Lehi Choke Point. In the future Lehi 2100 North becomes a freeway. South of Lehi Main Street, freeway volumes are projected requiring a future facility proposed in the plan. Future study will identify its location.

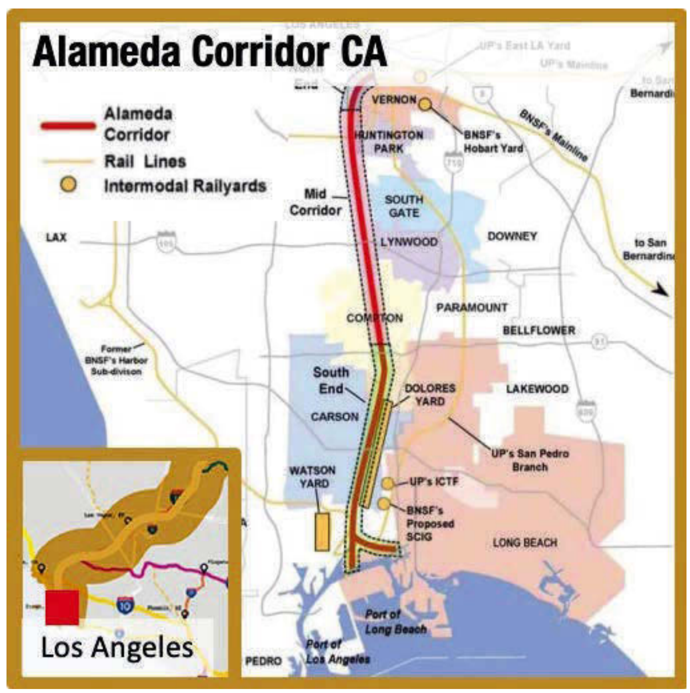
POINT OF THE MOUNTAIN CHOKE POINT

The Lehi area has some of the most challenging issues to transportation in the region. There are multiple choke points in Lehi impacting both north/south and east/west regional traffic. This coupled with high residential and commercial growth and being the center point of two metropolitan areas converging, only adds to the problem. The Point of the Mountain Choke Point is the narrow strip of land between Salt Lake and Utah counties. In the future, this area has more traffic, and more people traverse it than any other area in the region. Future projects proposed within TransPlan50 include improvements to I-15 and FrontRunner Commuter Rail, constructing the Mountain View Freeway, and Light Rail.

Source: TransPlan 40

3.7.7 Corridor "Stop" #4: Alameda Corridor

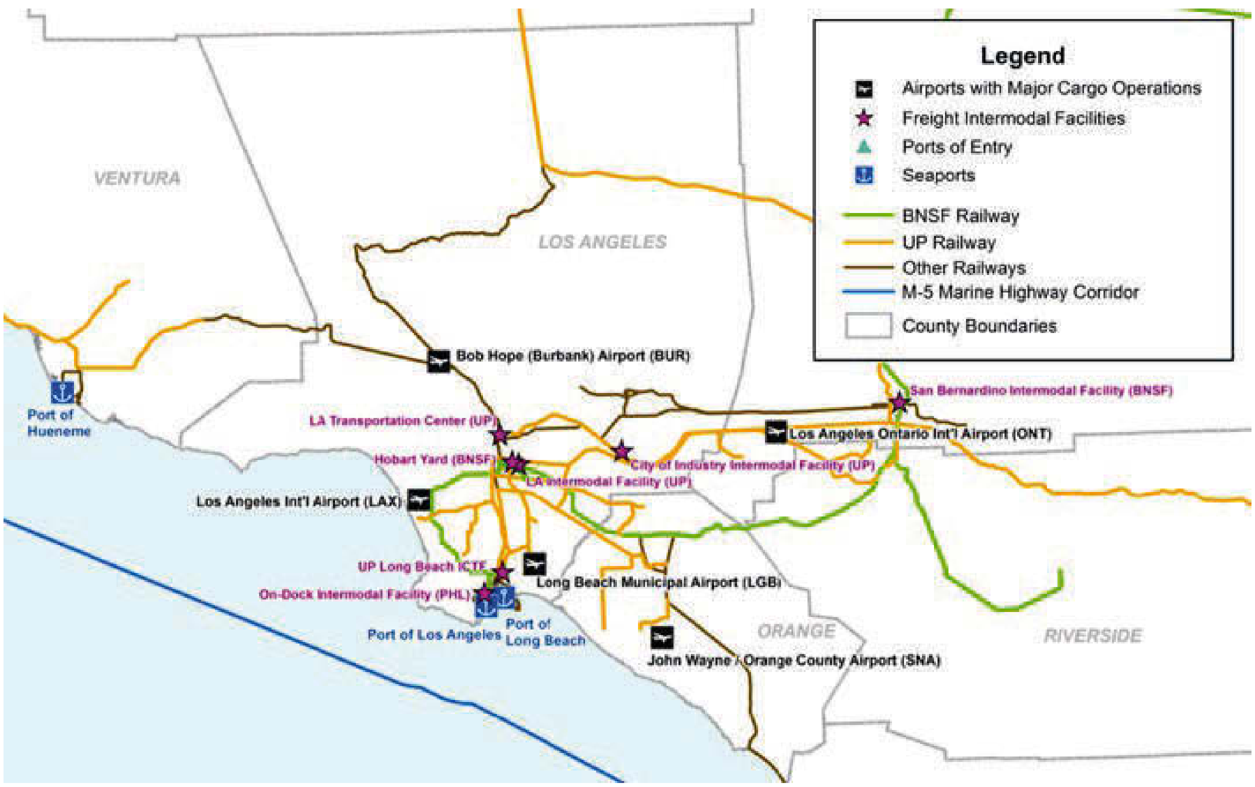
The I-15 corridor system enables California to exchange freight with Nevada, Utah, Idaho, Montana and Canada through its utilization of supporting interstates (I-105, I-210, I-610 and I-710) to access the port of LA Long beach. As the reach of this network extends towards this critically important port facility – North-South traffic in the final 40 miles from Vernon to Long Beach is heavily shaped by I-710's ancillary roadway - the Alameda corridor. The Alameda corridor provides critical access to manufacturing and freight facilities served by the port not accessible from I-710, thereby making its performance essential for the global exchange of goods on the entire I-15 system. Alameda has been described as a "**20-mile-long, grade-separated railroad intermodal corridor connecting the Port of Los Angeles and Port of Long Beach with the BNSF and Union Pacific main lines"… "**primarily of a below-grade, double-track mainline connecting central Los Angeles with the region's ocean port complex to the south." [161] In 2014, it averaged about 50 trains a day. It is located in the Los Angeles-Long Beach-Anaheim, CA



161 Jim Blaze, ed., "Is The Alameda Corridor in Trouble?," Railway Age, November 24, 2019, https://www.railwayage.com/intermodal/is-the-alameda-corridor-in-trouble/.

Metropolitan Statistical Area (2019 population of 13.1 million). The Alameda lies between and runs parallel to I-110 and I-710, which serve as truck freight access to (respectively) the ports of Los Angeles and Long Beach. Via the Harbor Subdivision, it serves the Chevron refinery on the Pacific Coast. There are six intermodal freight facilities near the corridor: one at each of the ports, the BNSF Hobart yard near downtown Los Angeles, and three Union Pacific yards, one of which is the City of Industry Yard. The rail mainlines serve all points north, northeast and east of Los Angeles. In a similar way, so do the Interstates for truck traffic. Los Angeles is the terminus of I-15 and along I-5. Transit service is provided by the (non-rapid) LA METRO Blue line. Most of the LA MSA area is gridded, but grid-scale varies—in some sections the superblock is 1 mile wide, half a mile in others, and .4 miles in another. Most of these superblocks are subdivided into a 'streetcar' suburb pattern consisting of long skinny blocks.

Exhibit 110 Intermodal Facilities



Source: 162

The Alameda Corridor

The Alameda Corridor was selected for special consideration because it represents one of the most widely studied efforts to date for improving freight rail performance to and from a major intermodal container port, reducing the number of heavy trucks on local freeways. It also reduced traffic along 90 miles of the Harbor subdivision, replacing it with a higher-speed grade separated corridor. "The Alameda Corridor consists of a

162 "FHWA's Roundtable on the Freight Economy: Los Angeles, California," U.S. Department of Transportation/Federal Highway Administration, March 22, 2016, https://www.fhwa.dot.gov/freighteconomy/losangeles.cfm.

series of bridges, underpasses, overpasses and street improvements that separate rail freight circulation from local road circulation. The outcome is a higher level of efficiency of both systems, particularly since a large number of rail crossings were removed. The main engineering achievement of the corridor is a 10 miles long 33 feet deep trench that virtually removes the rail infrastructure from the local communities. Construction started in April 1997 and the corridor began operations in April 2002."[163] The project was not a simple one. "The trench passes through six cities and the County. The design required local agency approval of their portion of the trench, and of the respective adjacent improvements."[164]

The Alameda corridor is only secondarily a rail project. The management effort owes its origins to concerns regarding the ability of the surface transportation system to handle increasing traffic near the ports, and the first phase focused on highway improvement; only in the second phase were the effects of increased train traffic considered and a consolidated rail corridor following the existing San Pedro brunch determined to be the preferred alternative, leading to the formation of the Alameda Corridor Task Force, which then concluded that "a Joint Powers Authority should be created to have design and construction responsibility for the Alameda Corridor, and the Alameda Corridor Transportation Authority (ACTA) was created in August of 1989.[165] Whether the corridor has reduced truck traffic is arguable.[166] Still, the ACTA stresses this was never the intent, but rather to "consolidate rail traffic and eliminate the 200 at-grade crossings along the previous routes, while minimizing the impact on communities."[167] In addition to reducing vehicular delay (as drivers waited for long freight trains to pass), the project was intended to reduce train noise and emissions, as well as vehicular emissions from stopped and idling vehicles.[168] Project objectives explicitly stated these dual purposes:

> *"The purpose of the Alameda Corridor project is to facilitate access to the ports through the year 2020 to accommodate anticipated growth, thereby reducing highway traffic congestion, air pollution, vehicle delays at grade crossings and noise in residential areas."*[169]

The trench was core to the anticipated effects. An at-grade solution with elevated automobile overpasses was preferred by the port, while the trench was preferred by local communities.[170] The project also included the massive Redondo Junction flyover also separated passenger trains (Amtrak/Metrolink), freight trains and street traffic, as shown in **Exhibit 111**:[171]

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[163] Jean-Paul Rodrigue, "The Alameda Rail Corridor," The Geography of Transport Systems, 2020, https://transportgeography.org/?page_id=2017.

[164] "Alameda Corridor," Tutor Perini, accessed October 26, 2021, https://www.tutorperini.com/projects/rail-mass-transit/alameda-corridor/.

[165] "History - Who We Are - Acta," Alameda Corridor Transportation Authority, January 6, 2021, http://www.acta.org/about/history.asp.

[166] Ajay Agarwal, Genevieve Giuliano, and Christian Redfearn, "The Alameda Corridor a White Paper," studylib.net, accessed October 26, 2021, https://studylib.net/doc/12435750/the-alameda-corridor--a-white-paper.

[167] "The Alameda Corridor Rail Project," Centre For Public Impact (CPI), September 2, 2019, https://www.centreforpublicimpact.org/case-study/alameda-corridor-rail-project/.

[168] "Completed Projects - about - Acta," Alameda Corridor Transportation Authority, March 3, 2021, http://www.acta.org/projects/projects_completed_alameda_factsheet.asp.

[169] "The Alameda Corridor Rail Project," Centre For Public Impact (CPI), September 2, 2019, https://www.centreforpublicimpact.org/case-study/alameda-corridor-rail-project/.

[170] National Academies of Sciences, Engineering, and Medicine, NCFRP Report 2: Institutional Arrangement for Freight Transportation Systems (Washington, DC: The National Academies Press, 2009), https://doi.org/10.17226/14332.

[171] "Completed Projects - about - Acta," Alameda Corridor Transportation Authority, March 3, 2021, http://www.acta.org/projects/projects_completed_alameda_factsheet.asp; "Projects - Shimmick-Heavy Civil Construction and Operations," accessed October 26, 2021, https://www.shimmick.com/projects/.

Intergovernmental coordination was key to the effort.

> *"The Southern California Association of Governments formed the Ports Advisory Committee in 1981. It included members of local government and industry, representatives from the ports of Long Beach and Los Angeles, the US Navy, and the Army Corp of Engineers. This later became the Alameda Corridor Task Force in 1985, and the Alameda Corridor Transport Authority in 1989. Membership of the Task Force was similar to the Committee with the addition of the California Public Utilities Commission and each of the eight cities along the proposed Alameda Corridor route."*[172]

Exhibit 111 Redondo Junction flyover

The large number of stakeholders proved unwieldy, slowing the process, as cities concentrated on impacts on their locality, rather than the overall objectives of the project. Consequently, the board size was reduced in size. The latter board consisted of 7 members: two from each of the ports, one from the cities of Los Angeles and Long Beach, and one from Los Angeles County Metropolitan Transportation Authority. The change in board generated lawsuits; post settlement, to prevent further delays, settlements and memorandums of understanding were negotiated with each city, providing financial mitigation in exchange for assurances that construction would not be delayed, or regulatory documents challenged.[173]

Private-sector funding (a fee per container-load from the railroads) proved important for obtaining Federal support (including a $400 million loan.[174] It made it possible for the ACTA to issue over a billion dollars in revenue bonds, creating a debt repayment structure that would grow as corridor volumes increased over time.[175] Correspondingly, ACTA continues to monitor the number of container units moving through the corridor.

[172] "The Alameda Corridor Rail Project," Centre For Public Impact (CPI), September 2, 2019, https://www.centreforpublicimpact.org/case-study/alameda-corridor-rail-project/.

[173] "The Alameda Corridor Rail Project," Centre For Public Impact (CPI), September 2, 2019, https://www.centreforpublicimpact.org/case-study/alameda-corridor-rail-project/.

[174] "The Alameda Corridor Rail Project," Centre For Public Impact (CPI), September 2, 2019, https://www.centreforpublicimpact.org/case-study/alameda-corridor-rail-project/.

[175] Ajay Agarwal, Genevieve Giuliano, and Christian Redfearn, "The Alameda Corridor a White Paper," studylib.net, accessed October 26, 2021, https://studylib.net/doc/12435750/the-alameda-corridor--a-white-paper.

Environmental analysis showed that the Alameda Corridor was preferred to the alternative, that of additional freight trucking.[176] Regardless, ACTA was mandated to monitor air quality in the corridor 2002-2005. ACTA also claims that the corridor has reduced pollutions through a truck to rail shift that reduced changes of vehicular crashes at crossings, improved emergency response times, and improved transit times and ridership.[177] This is reasonable, as it is "…in the interest of the freight rail advocate to document the external impacts and to demonstrate they are lower than providing equivalent highway capacity. In some cases, freight rail investment is justified in its capability to reduce external impacts alone."[178] In contrast:

> *"ACTA claims that the Corridor has slowed the growth of port-bound truck trips on the freeways and reduced idling of trains in the corridor, which has improved the air quality in the Southern California basin. There is no empirical evidence to support ACTA claims or quantify any benefits of the Alameda Corridor."*[179]

Lacking explicit metrics or targets, is it thus difficult to determine if the Alameda Corridor has met its declared objectives. However, in the case of reducing train-induced automobile delay, the gains may be so self-evident as to make measurement unnecessary. Still, without metrics it is impossible to gauge present success against an alternative investment strategy such as a grade-level corridor with overpasses. Analysis of corridor metrics was qualitative, rather than quantitative, in contrast to other freight capacity projects:

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[176] "Appendix E – Alameda Corridor," Appendix E – Alameda Corridor - Review of Environmental Factors - FHWA Freight Management and Operations, accessed October 26, 2021, https://ops.fhwa.dot.gov/freight/freight_analysis/env_factors/env_fact_app_e7.htm.

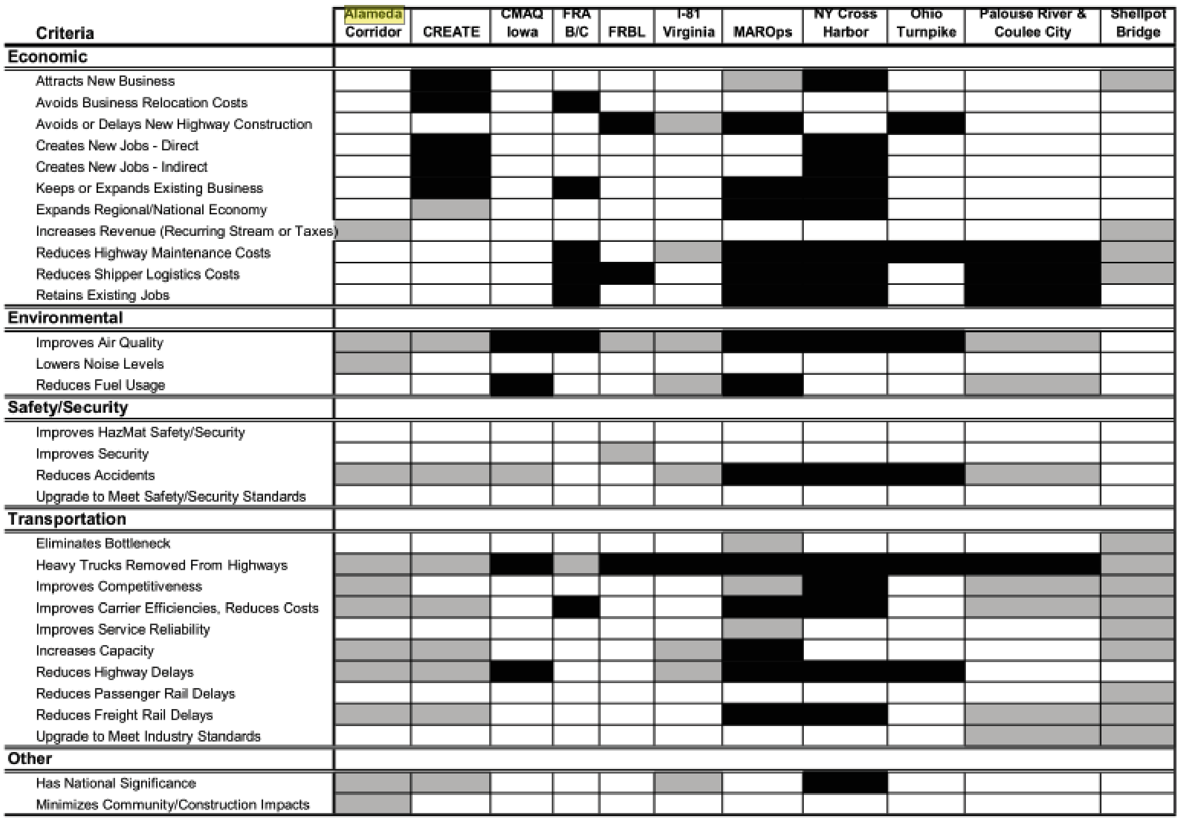
[177] "Environmental Benefits - about - Acta," Alameda Corridor Transportation Authority, March 2, 2021, http://www.acta.org/gen/environment.asp.

[178] David Hunt, "NCHRP - Transportation Research Board," April 2005, https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=1257.

[179] Ajay Agarwal, Genevieve Giuliano, and Christian Redfearn, "The Alameda Corridor a White Paper," studylib.net, accessed October 26, 2021, https://studylib.net/doc/12435750/the-alameda-corridor--a-white-paper.

Exhibit 112 Summary of Case Studies by Public Benefits Criteria

Quantitative Analysis – Black Shading, Qualitative Analysis – Gray Shading



Source: [180]

The corridor was designed and built during a time when trucking was fragmented and inefficient and has failed to capture as much traffic as anticipated. At the time of corridor planning, the use of double-stack intermodal cars had not yet become popular. However, the corridor trench is deep enough to support double-stacked containers in 'well cars,' facilitating the direct transfer of marine twenty-foot containers to rail, without the need to transload container contents. This is a necessity to overcome the need to eliminate transload maritime freight onto domestic containers and facilitate transfers directly from port to rail. "If transshipment costs and delays can be reduced, the corridor could gather additional traffic and fulfill the role it was designed for."[181]

[180] David Hunt, "NCHRP - Transportation Research Board," April 2005, https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=1257.

[181] Jean-Paul Rodrigue, "The Alameda Rail Corridor," The Geography of Transport Systems, 2020, https://transportgeography.org/?page_id=2017.

Alameda Take-Aways

The Alameda Corridor is instructive because (1) it illustrates how much can be assessed about a corridor strategy through a wide range of passenger and freight impact metrics and (2) it illustrates how differently evaluations of corridor impacts can come out – depending on the framework for assessment.

Many of the impact assessments above suggest that success in managing the Alameda Corridor appears more favorable if the framework considers the management effort less in terms of managing freight traffic than in terms of improving automobile connectivity, and quality of life for communities along the rail line. Much of the planning documented above (and consideration of impacts) was considered at a time when port activity and demand for rail transit were increasing and competing freight carriers (trucking) were perceived as disorganized and inefficient. However, these problems did not persist, to some degree obviating some of the strategies responding to the decision-point-in-time nature of ex-ante or single point observation of impacts.

While the corridor has been able to make debt payments, its financial viability has often been in doubt. While the Alameda corridor radically shortened the time required for freight rail to transit the corridor, the time advantage counts for little when burdened at the port by transshipment bottlenecks and north of the corridor by further corridor limitations. Trucking containers from the ports to existing intermodal facilities remains competitive, as does transloading goods from twenty-foot containers to fifty-three-foot American domestic sized containers. Freight rail is typically uncompetitive with trucking for short distances. As much of the freight unloaded at the port either has Los Angeles as the final origin or destination or requires processing/inputs in the Metro area, the ability of rail to capture more of the port's freight demand is limited.[182] “The Alameda corridor thus represents an unusual intermodal system for freight distribution. Its long-term success leans mainly on efficient intermodal handling both at the port cluster and at the rail yards.”[183] Whether this corridor can be said to be successful depends on the metrics used to assess success—the Alameda corridor is a freight rail project that provided relatively minimal rail benefits.

Alameda Corridor East

While the Alameda Corridor removed congestion along the corridor, it merely relocated the ‘bottleneck’ to a point further north to downtown Los Angeles—"rail freight traffic continued to be a problem between downtown Los Angeles along the railroads mainlines to the Cajon and San Gorgonio passes to the east.[184] This particularly impacted the San Gabriel Valley east of downtown Los Angeles.”[185]

There was a project to create an ‘Altamonte Corridor East’ to reduce road congestion at railroad crossings and improve safety by constructing grade separations at 19 rail crossings and eliminating 23 grade

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182 Ajay Agarwal, Genevieve Giuliano, and Christian Redfearn, “The Alameda Corridor a White Paper,” studylib.net, accessed October 26, 2021, https://studylib.net/doc/12435750/the-alameda-corridor--a-white-paper.

183 Jean-Paul Rodrigue, “The Alameda Rail Corridor,” The Geography of Transport Systems, 2020, https://transportgeography.org/?page_id=2017.

184 Jean-Paul Rodrigue, “The Alameda Rail Corridor,” The Geography of Transport Systems, 2020, https://transportgeography.org/?page_id=2017.

185 Trainsonthebrains and Trainsonthebrains, “Rail Service as a Public, Private Partnership,” ntbraymer, November 10, 2017, https://ntbraymer.wordpress.com/2017/11/10/rail-service-as-a-public-private-partnership/.

crossings, partially by placing part of the corridor in a trench.[186] In addition to freight, the Altamont Corridor East is planned for passenger rail: Amtrak and Metrolink presently, but also future High-Speed Rail line.[187]

Exhibit 113 Alameda Corridor - East Corridors

Source: [188]

3.7.8 I-15 System Takeaways

Main Street/Logan: The I-15 corridor is instructive in a number of respects. The Logan example demonstrates how a walkability index can provide a practical assessment for assessing a corridor's "walkability" when considering corridor alternatives. The "ViaCity" index demonstrated in Exhibit 84 is easily replicable when a city is an active partner in managing a corridor, bringing available information about bicycle and pedestrian infrastructure and traffic operations. The reality of Logan's main street is connecting its two major tributary routes to the I-15 system (US 90 and State Route 30) in association with its role as an economic asset to the community.

Metropolitan Salt Lake Region: There are several lessons learned from the regional management of the I-15 system in the Salt Lake City Region. The region is moving toward the adoption of more comprehensive corridor management performance metrics The regions MPOs, WFRC and MAG, have progressive land-use planning processes; Wasatch Choice for 2050 is a land-use vision that underpins their respective RTPs; MAG, WFRC and UDOT have also implemented a real estate market model that is used to iterate land-use and transportation responses as well as using the model to allocate pop and employment to TAZ structure.

[186] Project Overview: Alameda Corridor Project," ACE Project, accessed May 1, 2020, https://www.theaceproject.org/project_overview; Trainsonthebrains and Trainsonthebrains, "Rail Service as a Public, Private Partnership," ntbraymer, November 10, 2017, https://ntbraymer.wordpress.com/2017/11/10/rail-service-as-a-public-private-partnership/.

[187] Trainsonthebrains and Trainsonthebrains, "Rail Service as a Public, Private Partnership," ntbraymer, November 10, 2017, https://ntbraymer.wordpress.com/2017/11/10/rail-service-as-a-public-private-partnership/.

[188] Trainsonthebrains and Trainsonthebrains, "Rail Service as a Public, Private Partnership," ntbraymer, November 10, 2017, https://ntbraymer.wordpress.com/2017/11/10/rail-service-as-a-public-private-partnership/.

The region still manages corridors in a relatively isolated manner, and they have not adopted, at the operational level, the more comprehensive metrics used to develop their long-range plans and corridor studies. The area does have experience with corridor coalitions, but they tend to develop organically, based on individual corridor contexts. UDOT has implemented a comprehensive corridor/intermediate planning corridor planning process that does have a process that could help build corridor coalitions.

The state's unified transportation planning process is robust. The partners have synchronized planning cycles; they share a joint financial model and assumptions; they develop shared goals, objectives and performance measures across plans; and they have a policy board consisting of agency leadership and board that coordinate activities. Given the small number of MPOs and unique culture of Utah, it's not clear how much of this structure is directly transferable to other states and regions. Utah is also unique in that most of UDOT's capacity projects are funded with auto-related sales taxes, which make up approximately 17% of all sales taxes generated in the State of Utah.

Alameda Corridor: The Alameda Corridor is instructive because (1) it illustrates how much can be assessed about a corridor strategy through a wide range of passenger and freight impact metrics and (2) it illustrates how differently evaluations of corridor impacts can come out – depending on the framework for assessment. Many of Alameda's impact assessments suggest that success in managing the Alameda Corridor appears more favorable if the framework considers the management effort less in terms of managing freight traffic than in terms of improving automobile connectivity, and quality of life for communities along the rail line. Exhibit 112 demonstrates that despite the freight rationale for Alameda – the impact measurement efforts have been overwhelmingly qualitative – and have focused more on mobility than economic or trade considerations.

Exhibit 114 **I-15 Takeaways**

Topic	I-15 Takeaways			
	Strengths	**Weaknesses**	**Opportunities**	**Threats**
Truck parking	Good Inventory and implementation plan	Key areas need more parking	Smart Truck Parking and interregional cooperation	Governance, P3s, interregional cooperation
Commercial Vehicle Lanes	None	No dedicated lanes	With AV trucking there may be a willingness	Congestion in peak periods
Planning & Environmental Linkage (PEL)	Currently implementing PEL	Not fully integrated	Corridor planning framework	Institutional
Corridor Planning & Funding	Adopted corridor planning framework	The process is not always followed in its entirety	Integral part of project prioritization, use of broad performance metrics	Institutional
Public-Facing Open Data & Dashboards	UDOT has public-facing dashboards and an open data portal	Still focused on traditional metrics	Begin integrating land-use, economic, health and community metrics	Institutional
Corridor Management - Hazardous Incidents (Hurricanes, Snowstorms, etc.)	Implemented ICM program- incident management and integration of transit. UDOT has a sophisticated snow management program.	Just now implementing resilience in its workflows	Manage transportation network systemically	Integrating internal and partner workflows
Connected Vehicles (CV)/Integrated Corridor Management (ITS)	UDOT has a robust ITS program; UDOT and UTA have implemented a DSRC connected bus pilot	Planning and managing for CV/AV is in its infancy	There is an ongoing discussion with private sector CV providers; the Department has a dedicated position overseeing CV/AV adoption	Knowing the unknown
Performance Measures	UDOT has purchased HERE data and it using to measure real-time performance	Still focused on traditional metrics; have not integrated non-traditional metrics in corridor management	UDOT's project prioritization process considers a broad range of metrics; MPOs and UDOT develop joint planning PMs	Integrating internal and partner workflows

3.8 Other Observations

3.8.1 Corridor "Stop" 1: I-70

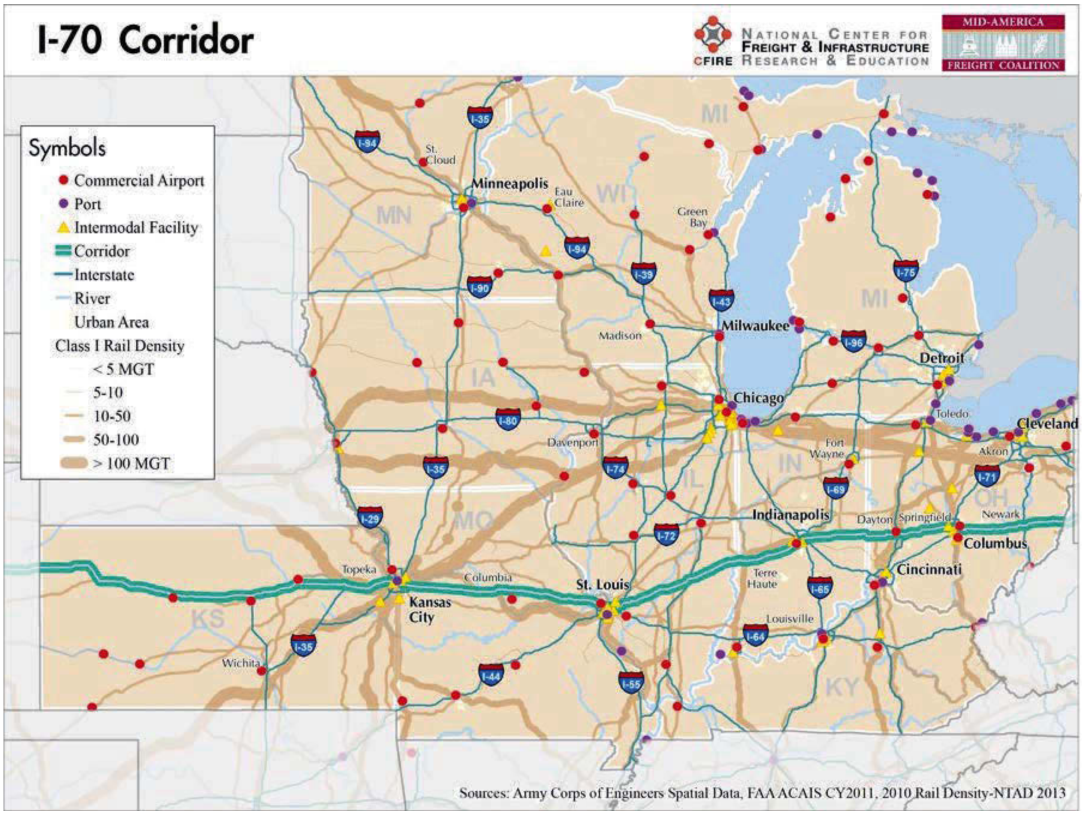
The I-90/94 national system is complemented by the trans-national I-70 system, which shares some of the same coalition partners with I-90/94 and can be instructive with regard to understanding how trans-national corridor systems address both similar and different issues. The Mid-America Freight coalition defined I-70 as the primary artery of the Heartland Corridor, passing through Kansas City, St. Louis, Indianapolis and Columbus; other cities include Columbia, MO and Terra Haute, IN.[189] St. Louis is the largest city, with a population of almost 3 million. Kansas City, Indianapolis and Columbus have populations of about 2 million. The corridor is over 1,200 miles long. In addition to the highway, the corridor has freight rail, passenger rail and a parallel inland waterway, M-70.

I-70 connects numerous interstates: I-29, I-35 and I-49 near Kansas City, KS; I-44, I-55 and I-64 near St. Louis, MO; I-65 and I-69 in Indianapolis; and I-71 in Columbus, OH; finally, it intersects with I-57 between St. Louis and Indianapolis. There are numerous intermodal terminals: two in Columbus (Norfolk-Southern railroad); two in St. Louis (CSX railroad and Norfolk Southern); two in Kansas City (Union Pacific and BNSF). There are over a dozen major rail yards, five airports, and five ports if the ones in Cincinnati and Jeffersonville are included. There are also four automotive distribution centers, over 20 major manufacturers and over a dozen major distribution centers.[190]

[189] "Mid-America Freight Coalition," MidAmerica Freight Coalition, accessed October 26, 2021, https://midamericafreight.org/index.php/rfs/network-inventory/corridors/profiles/i70/.

[190] "Mid-America Freight Coalition," MidAmerica Freight Coalition, accessed October 26, 2021, https://midamericafreight.org/index.php/rfs/network-inventory/corridors/profiles/i70/.

Exhibit 115 I-70 Corridor



The Mid-America Freight Coalition was formed to sustain the efficient movement of products in the face of growing congestion, in order to maintain the region's traditional advantages in transportation. Recognizing that freight movement across borders generated mutual dependence on transportation infrastructure for economic well-being, the existing Freight transportation center at the University of Madison-Wisconsin was leveraged to lead data collection, issue identification and facilitated dialogue.[191] The corridor coalition began under the name Mississippi Valley Freight Coalition.

Corridor Impact Metrics

The I-70 corridor uses a number of corridor impact metrics. In addition to population and employment, it also identifies GDP and freight-related employment for its constituent metropolis. It tracks the average combination Average Annual Daily Truck Traffic (AADTT) per mile for each of the major corridors in each city and along the corridor as a whole, as shown in the following graphic:[192]

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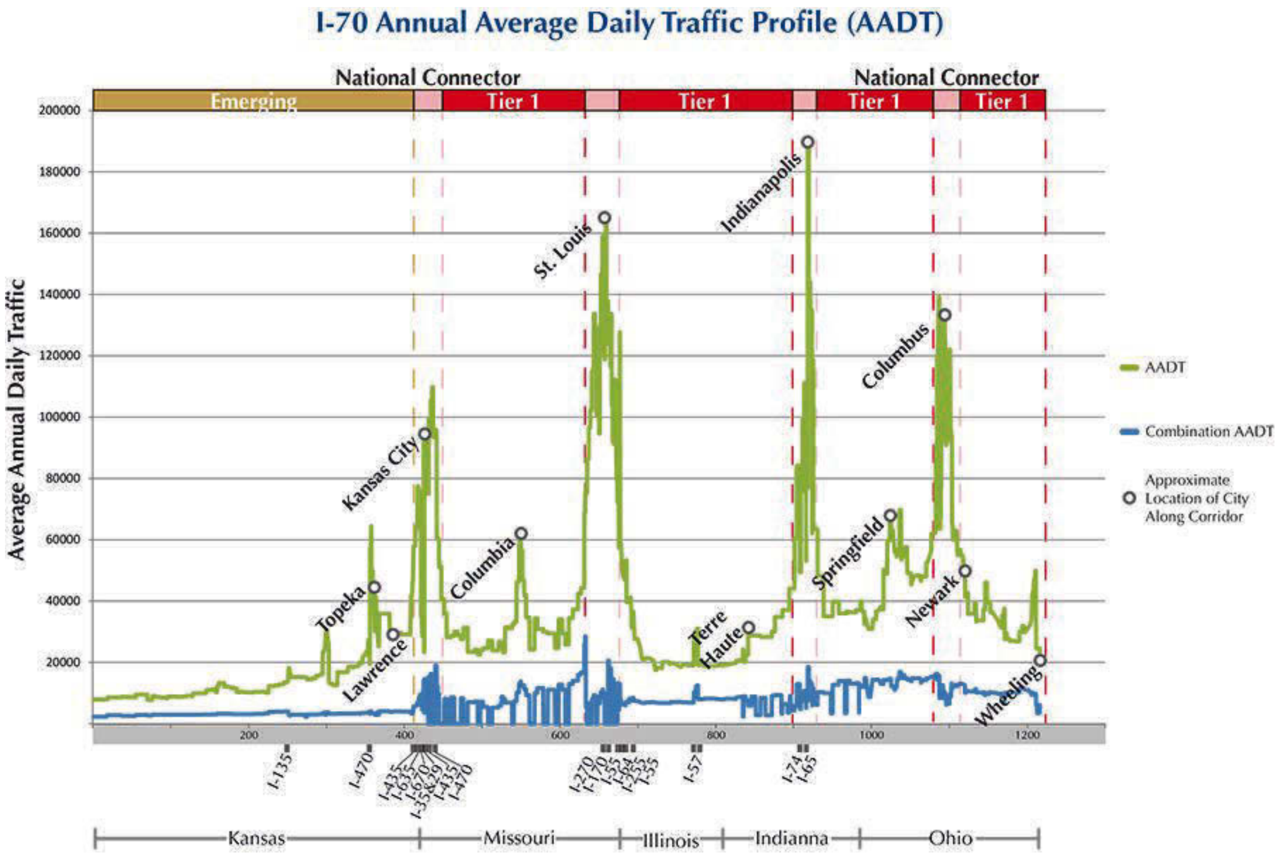
[191] "Mid-America Freight Coalition," MidAmerica Freight Coalition, accessed October 26, 2021, https://midamericafreight.org/index.php/about/moa/.

[192] "Mid-America Freight Coalition," MidAmerica Freight Coalition, accessed October 26, 2021, https://midamericafreight.org/index.php/rfs/network-inventory/corridors/profiles/i70/.

Exhibit 116 I-70 Annual Average Daily Traffic Profile



Volume to capacity ratio was used as a congestion metric, demonstrating that the corridor was largely uncongested, excepting within urbanized areas. Estimates of greenhouse gas emissions were made based on truck counts, assumptions of miles per gallon, and CO2 per gallon of diesel fuel; the availability of compressed and liquified natural gas fueling stations was recorded as well. Mean pavement roughness, which affects both safety and operating costs was tracked. Safety was also considered by tracking fatal crashes involving large trucks, as shown in the following graphic:[193]

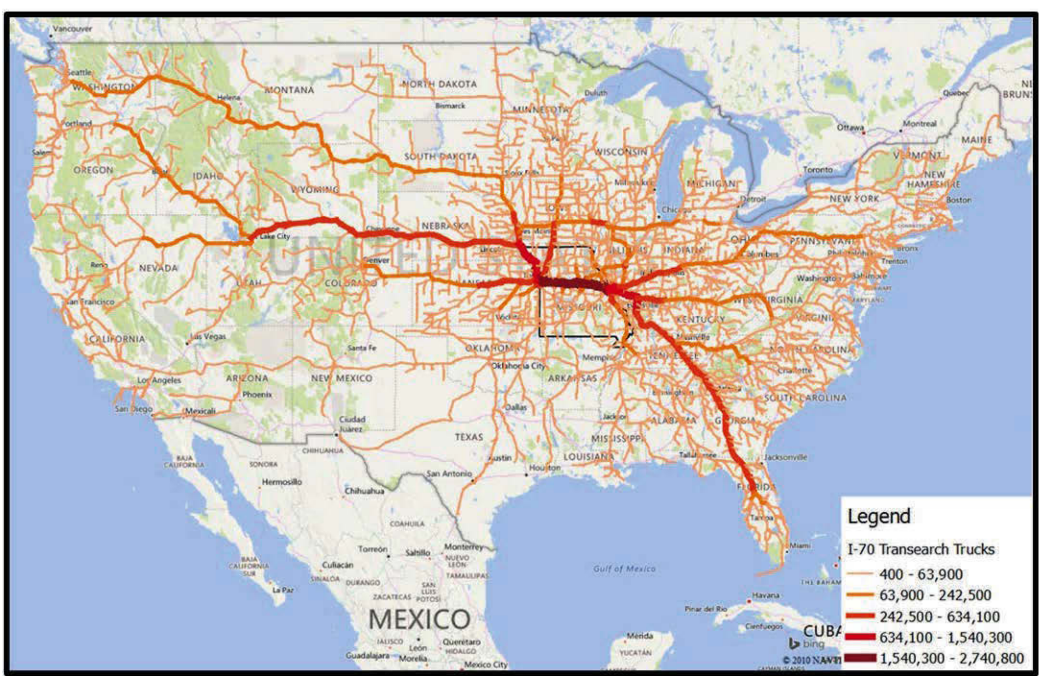
193 "Mid-America Freight Coalition," MidAmerica Freight Coalition, accessed October 26, 2021, https://midamericafreight.org/index.php/rfs/network-inventory/corridors/profiles/i70/.

Exhibit 117 I-70 Corridor Fatal Crashes involving large trucks

Along any given origin-destination pair, capacity on a corridor is limited by the worse bottleneck; improving capacity at a bottleneck improves connectivity and accessibility everywhere along the corridor, despite substantial distances from the bottleneck.

Recent federal grant applications have used ex-ante models as well as national commodity flow models including both the public Freight Analytics Framework as well as TRANSEARCH data, together with private input-output methods to both illustrate and quantify the national significance of I-70's traffic in Missouri. Exhibit 118 below demonstrates the extent of I-70's economic influence on the national economy, as illustrated using the national Oak-Ridge network in association with IMPLAN data.

Exhibit 118 Missouri DOT Analysis of I-70 National Markets (Tonnage)



3.9 Case Study Takeaways for Framework Development

The body of case research documented in this SWOT offers a window into how corridor entities are using data and measures to assess the impacts of both corridor performance and evaluate the potential impacts of strategies. It is notable that there were few if any instances of comprehensive sets of corridor management impacts applied at the national system level, and such impact sets were largely inconsistent between metropolitan areas within national corridor systems. It is also notable that while promising examples can be shown of a wide array of impact metrics, both with respect to land-use/transportation "D-Variables" and higher-level inter-city goods movement and capacity factors – the measures are seldom applied together for a strategically balanced view of corridor impacts. When reflecting on the state of the practice from this SWOT review of corridor impact methods – it is also striking that there is no coordination between those local coalitions and entities and the state, inter-city, or national coalitions, which often operate in isolation from one another.

The case research answers important questions about what it will take to offer an impact framework that will (1) significantly enhance the use of corridor impact metrics, (2) achieve balanced supply- and demand-side strategies, (3) understand impacts at key junctures in the corridor management process and (4) combine intelligence, resources and authorities as described in Chapter 2.2. This chapter of the SWOT focuses strongly on key elements of the framework that can address holistic observations about the requirements for a Next Generation Corridor Framework that integrates the wider 7-D approaches described in Appendix 4. These elements can be grouped into five framework categories supported by observations in the SWOT:

Scale and Geography: The review of corridor system impact practices offers insights into the need for scalable measures to different types of corridors and geographies, while still managing them as part of the same system and strategy. The case research above shows a range of corridor sizes and geographic areas and how they might assess impact differently.

Alignment with Role: In most of the case observations – the view of impacts resulted from a focus on what the corridor managing entities could do in terms of jurisdiction and what the corridor stakeholders had the authority to do that is important to consider when determining an impact assessment framework. This points to the need for a framework that is flexible for use by those with different levels of authority and jurisdiction – possibly associating particular impact areas with particular jurisdictional roles. The framework should also recognize and highlight, the limitations on the authority of the varied public-agency corridor stakeholders. This information is helpful to ensure a clear understanding of enforcement and follow-up responsibilities by stakeholders to evaluate the long-term success of the corridor management goals.

Comprehensive Time-series Measurement: Most of the observations in the case research revealed that corridor entities often do their most comprehensive assessment of impacts within the context of planning studies for the subject corridors, but they were mostly a snapshot-in-time. There were only a few examples of entities that had routine benchmarking or ex-post measurement to determine impacts or monitor performance as described in Chapter 2.2. Most of the routine analytics had to do with Intelligent Transportation System (ITS) operations. Additionally, the case studies showed heavy reliance on mobility and safety measures, which is consistent with the literature review. It did not reveal the use of a holistic suite of impact areas to round out the type of information needed to determine impacts from a variety of angles such as land-use and stakeholder perception.

Data Governance and Organization: The case studies illustrated a range of data sources and measurement methods. They demonstrated a need for a framework to help provide some standards - methods for data organization and governance, industry-tested and approved measurement methods and data sharing and collaboration opportunities.

Coordination and Communication: An important element for success in corridor management appears to be coordination and institutional organization. There are roles for state Departments of Transportation (DOTs), Metropolitan Planning Organizations (MPOs), cities, counties and other stakeholders. Some of the case studies demonstrated organizational plans and routines that appeared to help in the operations of the corridor. Additionally, there is a growing use of communications tools and dashboards to disseminate information.

These are described in further detail below.

3.9.1 Scale and Geography

The case studies covered the way that corridor managers understand impacts across wide-reaching geographic, economic and performance impacts for intricate corridor systems spanning throughout the United States (U.S.). The observations have focused on what is taking place for corridor management throughout these corridor regions. The entities involved in corridor management ranged from very large multistate corridors such as the I-95 Corridor Coalition to smaller, urban area corridors and neighborhoods. From the findings of the above case research, it is clear that corridor management can be defined differently depending on the entity and its goal. For the purpose of this work, it has been broadly defined. While varied definitions of corridor management and its impact are both necessary and helpful for enabling management to occur at different levels – a lack of associations between corridor management definitions (and when or how to apply them) is problematic.

By looking at national corridors as singular, nested systems – it is clearly observed that depending on the type of entity and its jurisdictional scale, stakeholders may at once about different corridor management strategies or focus on different outcomes. For example, the I-95 Corridor Coalition (I-95CC) exists to improve efficiency along the eastern seaboard. It has been effective in doing corridor-level bottleneck analyses for truck and rail operations, as well as providing access to states and Metropolitan Planning Organizations (MPOs) to data sources that can support their own measurement programs (I-95) (I-95 Corridor Coalition, 2009) (I-95 Corridor Coalition (a), 2009) (I-95 Corridor Coalition, 2020). In this case, a framework for measuring the impacts of their corridor management efforts needs to be scaled for large, multistate, inter-regional, or local performance. Local land-use impacts would be less relevant in inter-city case than macro-level measures of performance for the eastern seaboard or even the nation. Alternatively, MPO regions or municipalities in the case studies have a different perspective and would likely care significantly about land-use impacts, local economic development, ridership or vehicle throughput. Both types of entities may care about outcomes like jobs, delay, and environmental measures, but their jurisdictional boundaries, and therefore their interest, would be at different scales. The challenge of a Next Generation Corridor Framework is to intentionally utilize these different scales in harmony – instead of focusing myopically on one are only for outcomes to be undercut by inconsistency or failure at another level that was seen as “out of scope” of the management effort.

It is also important to consider neighboring entities or parallel corridors or regions. The case studies showed that in many of the plans or corridor management organization schemes, it was necessary to consider what was happening in parallel or adjacent regions. Examples such as the Alameda Corridor in California, the Downeaster in New England and the 15-501 corridor in North Carolina were all exemplary of this need. At some point, everything is part of a system and can affect changes in other areas. All corridors, for example, are part of the national system, and regions within corridors are part of the corridor system. Understanding corridor impacts requires not just focusing on the corridor identified, and the strategies at play, but also looking outside to understand its effect.

3.9.2 Alignment with Role

Another consideration for corridor management impacts is what the entity doing the management is legally able to do (or cares about) depending on their location, and how to align a framework for corridor impact analysis that aligns with these jurisdictional roles. For example, very large organizations (e.g., rail-focused corridor groups) may not be able to effect change for urban boulevards or land-uses at local or regional levels. Additionally, different geographic areas may prioritize different strategies. In the case studies, Virginia was more focused on ITS solutions, while the Atlanta regions prioritized freight flows as their focus. They are both still members of the I-95 corridor, but they cared about different things and had different jurisdictions as well.

Additionally, some corridor efforts had prescribed goals for different types of management like ICM, freight or transit. They may not have ever set out to focus on land-uses or sustainability, for example, even if those areas are important for impact analysis. Their focus may be on implementing TSMO strategies or how to improve rail efficiency and connection. Regardless of type, any framework or way to measure how well corridor management is working must consider and align with the role and the associated goals and objectives of what the corridor management activities set out to do. While it can consider unintended impacts, knowing what the goal is will help to assess whether strategies are working as planned, and then measuring other impacts can shed valuable information on how different types of goals affect different areas. Such an exercise could also identify if the goals of one jurisdiction are being met by the corridor management activities of a different jurisdiction or vice versa.

3.9.3 Comprehensive Time-Series Measurement

The case studies demonstrate a need to consider ways to broaden impact analysis and think about corridor management outside of specific roles or alignment. The case studies and Appendix 2, it is shown that there were two main divides among corridor management efforts: 1). There were those that focused on the relationship of planning and development with transportation in ways that helped the vitality of a corridor, and 2) there were those that focused on ICM. While there were a few that had combined priorities, the two types of corridor management efforts were presented differently. Additionally, there were those that focused on all traffic movement, just transit and just freight.

There seemed to be purpose-driven plans, studies and programs for the various corridor efforts that were driving what got measured and what got done. For the most part, these assessments were, as mentioned before, snapshots-in-time or assessments that were done at the outset of pursuing a specific purpose for corridor management.

Error! Reference source not found. to the right shows that of all the observations made at corridor "stops" in the SWOT – a review of existing practice finds significantly more ex-ante methods than ex-post or benchmarking approaches.

Exhibit 119 SWOT ex-ante and ex-post measures

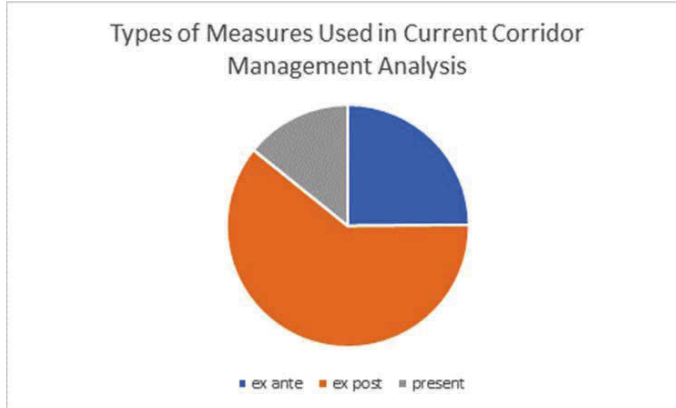
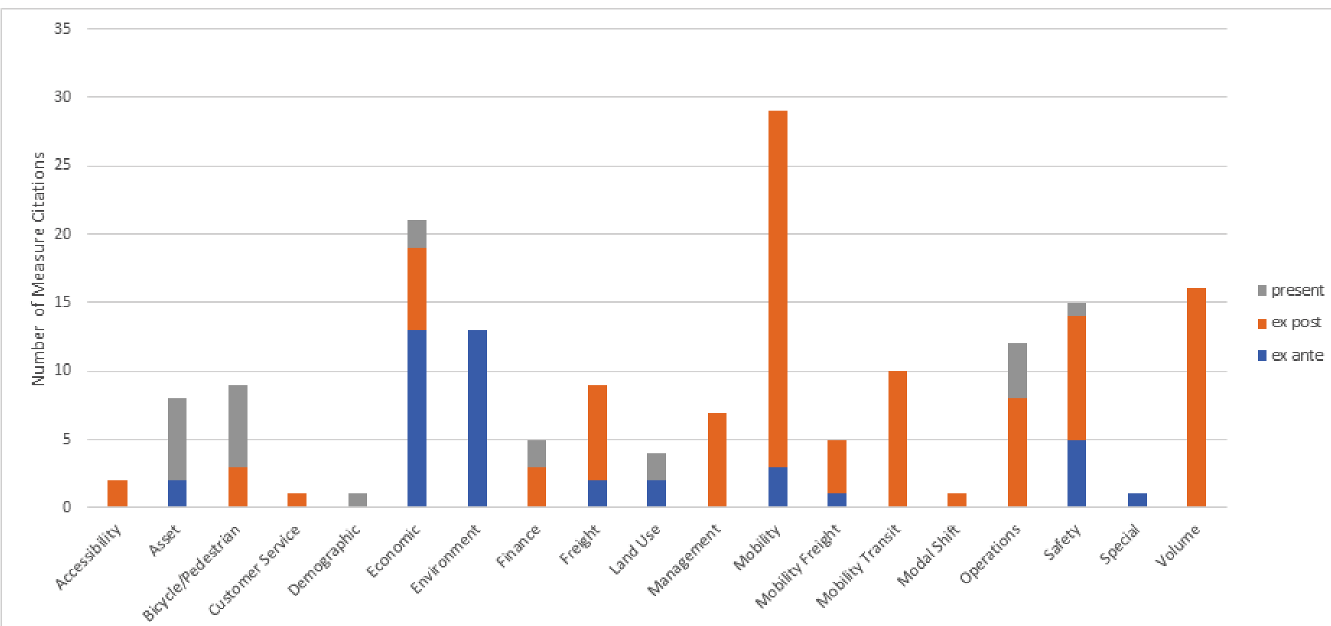


Exhibit 120 below further demonstrates how these three types of impact assessments explored in Chapter 2 were prevalent for different corridor performance areas observed in the case research. It should be noted that this SWOT is a descriptive review of corridor systems. It is not found that these shares are necessarily representative of corridor management everywhere. However, the charts reveal the tendencies observed of many agencies to collect and report retrospective trend data or project anticipated performance, with comparatively little "present-time" benchmarking between decision points.

Exhibit 120 SWOT ex-ante and ex-post measures by topic



However, some entities like the Boston Region MPO, Georgia Department of Transportation (GDOT) and the South Florida I-95 Mobility Corridor did have a routine assessment of corridor management impacts with a suite of measures approach that looked at the corridors in a more comprehensive way. This will be explored later, but these entities demonstrate how to apply a set of measures routinely to assess performance, and they seemed to be pushing the boundaries and innovating on corridor management impact assessment in ways that some of the more specific efforts could be expanded.

Consistency in Measures for Ex-Ante, Benchmarking and Ex-Post Impact Assessments

Similar to the purpose described above, the case studies revealed that there are only some measurement areas that are considered throughout the management process. In contrast, more comprehensive measures that include areas like asset condition, resilience, environment, accessibility, and land-use impacts were measured less often and sometimes only once in an initial study.

The case research findings of this SWOT point to a relationship of measures – both across geography (national, inter-regional and local) and across time. Measures of corridor management performance interact with each other in decision-making. For example, a takeaway from case studies in the I-95 region was that along origin-destination pairs, capacity on a corridor is limited by the worst bottleneck. Improving capacity at a bottleneck helps to improve connectivity and accessibility everywhere along the corridor even when there are major distances from the bottleneck. Therefore, it appears necessary to expand corridor management impact analysis to include measures beyond those that are common to those that can help illuminate the story of what is working or not working for the corridor from an “ultimate origin-destination” viewpoint.

It is likely that mobility, safety and economic impacts are easier to measure due to more standardized methods and relatively available data. They are also more responsive to supply-side actions by state transportation departments (which often play leading roles in management efforts). Other impacts like land-use changes and accessibility may be harder for corridor management entities to quantify.

Foundations in Practice for “7-D” Approaches Balancing Supply & Demand

There were some entities that are demonstrating the use of more comprehensive measures beyond mobility and safety. The measures found in the SWOT that look into destination access, demographics, diversity and other “D” variables and will create ingredients for the 7-D next-generation concepts of subsequent reports include the following:

- **The Southeast Florida I-95 Mobility Corridor** includes accessibility and measures it with travel time to and from locations, proximity and speed. It also measures trip density by assessing the average trip lengths from a Transportation Analysis Zone (TAZ) to TAZ and does so across modes.
- **The Atlanta Regional Commission** (ARC) includes measures that compare land-use and zoning codes for more consistent land-use/zoning planning.
- **Wasatch MPO** uses a travel demand and land-use model in its planning process that is a variant of UrbanSim. This tool, called the Real Estate Market Model or REMM, gives MPOs the ability to estimate the positive or negative impacts of planned transportation investments on walkable land-use objectives. While this is a planning tool, it could be used in the assessment to determine what benefits were expected and what actually happened.
- **The Utah Department of Transportation (UDOT)** has a new project prioritization model that reflects economics, land-use, accessibility and quality of life metrics in addition to the more traditional metrics of mobility and safety. This is a planning tool, but like the Wasatch model, it could be used in the assessment.
- **In Dallas**, land-use compatibility analysis was used in a study of freight congestion and delay, and this could be used in more routine impact analysis.
- **Metropolitan Council MPO’s work in Minnesota** on integrating land-use into transportation planning

shows the use of measures such as:
    - Influence on travel demand via land-use policy.
    - New multifamily housing along transit corridors.
    - Increases in downtown residents.
    - Average land utilization rates.
    - Acres per 1,000 new residents.
    - Acres per 1,000 new households.

- **Minnesota Department of Transportation (MNDOT)** uses a measure of accessibility to intermodal through truck to rail transload facility truck generation by geofencing freight locations.
- **Heartland Regional MPO** is incorporating numerous environmental measures, including reduced fuel consumption, air quality measures and other sustainability impacts.

While these examples are promising in showing that there are other measures in play beyond mobility and safety, there were only a few examples of more comprehensive and/or routine analysis using measures to see how corridor management was working and then being used to guide stakeholder discussions for changes or investment. Most of the above comes from single studies or analyses done to assess the corridor as is and not necessarily to assess how well corridor management strategies are working.

For ICM, the case studies include both the Virginia Department of Transportation (VDOT) and the Georgia Department of Transportation's focus on operations (VDOT, GDOT). Their use of dashboards included measures of mobility and safety, as well as expanded measures for operations such as elements related to roadside units, incident management, and other TSMO operations.

In addition to some of the ICM impact analyses, Boston Region MPO demonstrated the most comprehensive, routine assessment of corridor management through its development of the New and Emerging Metrics for Roadway Usage study in 2019 (Boston Region Metropolitan Planning Organization, 2020). The purpose of this work was to improve multimodal performance monitoring of the mobility of individual travelers. It contrasts with a more traditional approach focused on the vehicle throughput of a corridor. The measures are comprehensive of many areas and are incorporated into the MPO's planning processes, including the congestion management process and the long-range transportation plan. They applied this suite of measures to two, one- to five-mile corridors selected by the MPO for testing. They were able to determine, for example, the impacts and outcomes in the corridor to understand bicycle and pedestrian movements, bus ridership, passenger car mobility, and freight movement (Boston Region Metropolitan Planning Organization, 2020).

Therefore, though comprehensive corridor management impact analysis is lacking in the U.S., there are measures and some limited routine assessments and practices related to corridors that can be incorporated in an analysis framework. In the plays of the Playbook (and supporting appendixes) there is a suite of comprehensive measures that touch on all the areas of impact and is designed for jurisdictional scale, alignment and purpose of any corridor organization.

There are some opportunities to build on previous work in access management, ICM and data for decision-making in order to understand how they have applied frameworks for analysis of an area. For example, there has been a significant body of work by TxDOT that researched methods and guidelines to engage in corridor management and preservation on Texas roadways through the coordinated application of state and local plans and regulations. This work looked at a range of areas such as regulatory components, zoning, and ROW acquisition and recommended best practices. This research is useful in identifying the range of impact areas to measure. The findings presented here for measures used can be aligned with the impact areas Texas has identified in order to build a holistic approach (Hard, Ellis, Bochner, & Spillane, 2008).

Additionally, there is guidance to be learned from access management efforts. For example, the FHWA highlighted best practices for measuring access management treatment impacts to show the importance of looking at impacts from a variety of perspectives, as well as the need for coordination among a range of stakeholders (Federal Highway Administration (a), 2015).

FHWA also studied comprehensive ICM impacts (Federal Highway Administration, 2009). Their work used a suite of measures and applied them to ICM corridors. Their measures included mobility, safety, air quality, cost-benefit, institutional and organizational issues, sustainability and some land-use elements.

Finally, lessons from the data for the decision-making arena can help in understanding comprehensive suites of measures to support the analysis of corridors. An approach pioneered by the Texas A&M Transportation Institute (TTI) called the TOol using STAcked DAta (TOSTADA) examines a comprehensive set of conditions and performance measures and weighs those factors to help determine where transportation improvement projects make the most sense. The TOSTADA model uses geographic information system tools to illustrate color-coded maps for analysis factors, including asset condition, mobility, safety, and freight value. The intent is to use multiple data sources to draw insights and to encourage improved project comparison and selection by transportation agencies. (A guide for applying the TOSTADA methodology is included in Chapter 4.8 of *NCHRP 917* published in 2020 and is further developed in a corridor setting as described in Appendix 12 and Play 4: Build a Spatial Analysis Environment.)[194]

These examples provide excellent options to use when implementing the plays of the Playbook. The lessons learned here aligned with the ways current corridor agencies are already measuring performance, either in a snapshot or routinely, can contribute to a framework that helps agencies consider impacts in the most holistic way.

3.9.4 Data Governance and Organization

The ubiquitous use of mobility and safety measures, as well as economic and operations analysis, matches with the robust availability of the data for these categories. There are numerous data sources for mobility measurement, safety analysis, and resources to describe economic activity that can be used in a Benefit-Cost-Analysis (BCA) or other impact analysis. TSMO operators have data and measures for their day-to-day deployments of ICM that could also be used.

The case research pots to significant challenges in data governance and organization as barriers to the type of comprehensive framework envisioned in Play 2: Take Inventory of the Corridor. The use of data and measures is not consistently applied. Under current practices, it is not possible to adequately compare corridors, or even regions, within mega-corridors due to the myriad of ways corridor entities are using data and measures.

[194] National Academies of Sciences, Engineering, and Medicine, *NCHRP-917: Right-Sizing Transportation Investments: A Guidebook for Planning and Programming* (Washington, DC, 2019), https://doi.org/10.17226/25680.

Data come from multiple sources and are not, all the same, depending on the category. There are numerous probe data providers for mobility data and there are differences among these data sets. Crash data are not always coded the same from state to state or from locality to locality. There is a lack of consistency.

Additionally, different entities have varying degrees of access to data. One with little access might use it to do a small study. One with resources for more access might use it for routine measures and for dashboard visualizations to monitor performance. The case studies referenced some data sharing and partnerships that could be reviewed for the framework development. Organizations such as the I-95 Corridor Coalition develop data markets such that its members can access data through one agreement more easily and cheaply than if they had to pay for it separately and engage in public contracting.

There are also emerging data sources, especially with crowd-sourced travel data and connected and automated vehicles (CAV) that are providing opportunities for performance data in new and different ways. Some of these data may be big data requiring the use of sophisticated analytics and analysts with data science skills. In any framework, it will be important to recommend some ideas or methods for data governance and working toward consistent applications.

Consistency is required with performance measurement as well. The body of case research in this SWOT shows a range of ways corridor entities are applying measures. Some use industry-tested and approved measures, especially for mobility. Others are applying measurement inconsistently such as variance on inputs for BCA. A framework should guide corridor entities toward the most defensible way to apply measures and tell the corridor management impact story.

It did appear as though many of the corridor management entities are improving their data and measurement capabilities or investing in new resources and dashboards. This may be a result of the recent federal mandates for performance, such as the Moving Ahead for Progress in the 21st Century (MAP-21) as this was cited in Appendix 2 and referenced in some of the case studies and some of the measures used to align with the federal requirements for MAP-21.

3.9.5 Coordination and Communication

The body of case research in this SWOT shows that coordination and communication are important elements for the corridor management impact framework. Entities demonstrate a range of organization types, as well as ways that they communicate with stakeholders.

TxDOT, for example, has identified that coordination among the agencies and departments involved in corridor management activities is important and necessary. For corridor management to succeed, it requires effective interaction among entities involved at various stages of planning and ongoing activities. TxDOT also provides a review of strategies for the institutional organization of corridor management entities and the agreements among stakeholders (Hard, Ellis, Bochner, & Spillane, 2008).

Many of the case study entities described the formation of corridor coalitions, their purpose and the roles of stakeholders. In the I-90/94 corridor, stakeholders came together to focus on freight efficiencies and ITS implementation and coordination through many states. In the Alameda Corridor, stakeholders came together to focus on rail efficiency, but there were interests from a broader freight and land-use perspective. The I-95 Corridor Coalition's goal was to improve the corridor along the entire eastern seaboard by providing corridor-level research and equitable access to information and data for all states and MPOs. The organization and definition of roles among these organizations appear as an important component of corridor management strategy success.

Additionally, several case study entities had effective communications tools like dashboard visualizations that provided routine continued information to stakeholders. This communication is an important element that puts all stakeholders in the position of understanding performance in clear and easily understood ways. A framework for measuring impacts might be accompanied by a prescription for some organizations and methods for corridor management function and dissemination of performance information.

3.9.6 Path Forward for Next-Generation Corridor Framework

What the key takeaways from the case studies reveal is that there are some traditional practices, especially in mobility and safety awareness, but gaps exist. The five categories described above help to set up a framework concept, but there are some other observations that inform the overall guidance the Playbook provides for corridor management impact analysis. These include improving some measure categories that are less used or developed and corridor management organization application of the framework.

Measure Development

The case studies show that there is a lack of measuring impacts on areas like land-use, mode choice and shift, and measures that capture stakeholder perceptions and agency management. These types of measures can make an understanding of how well strategies are working more robust and help to reveal the relationship between strategies and impact areas. In implementing the plays of the Playbook, it is important to focus on the development of defensible approaches to these areas. Fortunately, there are some examples in the case studies that can inform the framework development.

Specifically, an important area to improve is the understanding of land-use impacts related to transportation investments in a corridor. Previous work in this area for the Texas Department of Transportation (TxDOT) cites the long-term consequences of not managing land-use and development along major corridors, and the failure to plan for the future. These consequences include increases in congestion and crashes, negative impacts on property values, aesthetic challenges, economic disinvestment, housing and business displacement, encroachment of residential on freight facilities, and challenges with right-of-way (ROW) and increased project costs (TTI). ROW was described in the case studies as a problem being a scarce resource and something that should be measured or monitored in any framework because effective management of the transportation system requires consideration of current and future ROW, and actions to preserve it.

Changes to Corridor Management Practices

The Playbook offers a framework that is most effective when the impact methods of Appendix 5 are implemented in assessing strategies as described in Play 5: Select Strategies and Supporting Methods/Data. The corridor orientation tool offered in Appendix 7 and Appendix 8 can guide agencies and jurisdictions engaged in corridor management that outlines steps, procedures, and responsibilities that would facilitate their ability to work cooperatively on corridor management and measure its impacts.

First, it is important that there be a corridor management plan and/or goals and objectives that speak to the aspects of corridor management to be addressed and their desired outcomes. All agencies and entities that have regulatory authority in and along the corridor (e.g., planning, operations, land development, etc.) should be involved in the development and adoption of the plan and goals.

Second, it is also important that there be a baseline assessment of the corridor to understand the current state of the corridor. For the case study corridors, this was mostly done in a snapshot or one-time study, plan, or grant application. However, repeating the measurement is important so that various jurisdictions can understand how strategies are working (or not) over time. Therefore, the framework application guidance should come with a recommendation for an initial assessment and frequent, subsequent assessments.

Third, the data governance and standards mentioned above should be vetted and used by the corridor management entity or coalition to ensure consistent, defensible monitoring and analysis that can be compared to other corridors and stand up to rigorous reviews of federal grant applications and other financial pursuits. The framework can help to address this and recommend options.

Fourth, a methodology for when to apply the framework, frequency and how to coordinate with stakeholders will help with the success of measuring impacts. For some organizations, more routine or frequent measurement might be needed depending on the level of activity. For other organizations such as very large corridor entities, a yearly assessment might be best.

Finally, communication among stakeholders is important so that everyone involved understands progress. There were several examples of communication tools and strategies in the case studies. Awareness of performance and the ability to see performance holistically as mentioned above, with the need for comprehensive measures, is a necessary component.

3.9.7 Conclusion

Appendix 4 and Appendix 5 address measurement gaps and support implementation of corridor management plays that can illuminate how well corridor management works and how impact analysis can be used in decision-making and investments. While Appendix 2 and the case research shown here reveal little in the way of comprehensive, continuous measurement and incorporation into planning, the work that has been done provides a strong starting point and level of sophistication among corridor entities that can serve as the foundation of a more comprehensive framework.

This body of case research has been intended to demonstrate successful practice as well as anticipated challenges for practitioners using the Playbook.

Freight

Best Practices in Land-use/Sustainability	Key Advances from State-of-the-Practice to State-of-the-Art	Specification/Target for Next Generation Corridor Framework
I-95/I-85 Corridor: GDOT developing dedicated commercial vehicle lanes on I-75	First commercial vehicles only lanes in country focused on improving mobility for freight and vehicles	*Framework offers an interpretation of "7-D" variables in both the urban and inter-city freight context, with associated roles for local, inter-regional and national partnerships.*
GDOT Truck Parking Study	GDOT working to develop state-wide truck parking study analyzing what is available and what needs there are	*Framework offers widely acceptable data guide for making these considerations practical to apply.*

Land-use/Sustainability/Resilience

Best Practices in Land-use/Sustainability	Key Advances from State-of-the-Practice to State-of-the-Art	Specification/Target for Next Generation Corridor Framework
I-94 Corridor: Prioritize livability in communities while enhancing mobility, safety, and interconnectivity by developing public engagement toolkits and community culture handouts	Develop public education materials to change public's views on how transportation can be beneficial to them and enhance their community's values	*Framework offers an appropriate level for addressing land-use and sustainability in the corridor management process, with roles for entities with best suited to contribute land-use solutions.*
I-95/I-85 Corridor: PEL to coordinate planning and environmental efforts, expediting NEPA planning	Understand the impacts transportation has on environmental factors, and expedite the process of FHWA approval	*The framework demonstrates the impact measures that can be evaluated and tracked at different levels. Inputs, procedures and outputs for such analyses will be demonstrated. These may range from dashboards and models to simple self-assessment checklists, building from the practices and needs observed in the SWOT.*
Conflicting Land-uses: Evaluate and compare land-use and zoning codes against mobility for more consistent land-use/zoning plans	Evaluate land-use/zoning laws that may conflict with transportation mobility goals	
I-15 Corridor: Travel demand projections based on 7D activity centers and livable corridors – focus on increasing density, diversifying uses, minimizing distance to transit	Incorporate 7D activity centers and livable corridor metrics into travel demand model to understand impacts on land-use plans	*Framework suggests an appropriate relationship between local management efforts at the city or neighborhood level and larger national and inter-regional strategies.*
Envision Utah – transit/land-use paradigm shift through public and political education	Develop public education materials to change public views on transit/land-use	
Land-use connection program – Policy board of local officials modifying zoning and regulations to encourage mode shifts	Use local officials to lead efforts in changing zoning regulations to encourage transit/biking/walking modes	

Mobility/Performance Measures

Best Practices in Land-use/Sustainability	Key Advances from State-of-the-Practice to State-of-the-Art	Specification/Target for Next Generation Corridor Framework
5/I-85 Corridor: GDOT RTOP for 10 years – signals report data to dashboards to help measure performance	Provides real-time data to enable GDOT to analyze impacts on the network daily, monthly, yearly	Framework addresses the issue of standardizing mobility and performance measures based on the practices of management partners (as opposed to one-time top-down studies).
VDOT Corridor Planning from state line to state line – understand operational needs from rural to urban areas	Adopt one-size-doesn't-fit-all approach to planning – can see entire corridor in real-time instead of specific areas	The framework considers linkages between state and MPO targets and corridor-wide targets at national, state and local levels.
MassDOT focus on performance of individual passengers instead of vehicles – roadway lane density and person throughput	Enables multimodal performance measures to look at rail/transit instead of just roadways	The framework considers the role of the Federal performance measures in relation to the underlying diversity and rationale of local and regional measures.
FDOT multimodal performance measures	Bring all rail/air/freight/DOT/ MPO officials together to develop measures that are used in all plans	
I-45 Corridor: Dallas/Houston MPO metrics include first/last mile connections, truck parking, and inadequate infrastructure	Focus on metrics not related to roadways/traditional performance measures	
I-15 Corridor: UDOT consciously moving away from traditional performance metrics to analyze future issues.	Understanding need to plan for future issues and not just on roadway issues today	
Wasatch Front Central Corridor Study – have PM that reports to management committee comprised of senior officials from each agency	Reporting paradigm that enables all agencies to vote on metrics and policies – enables standard metrics across all agencies	

Economics

Best Practices in Land-use/Sustainability	Key Advances from State-of-the-Practice to State-of-the-Art	Specification/Target for Next Generation Corridor Framework
I-94 Corridor: GNC Coalition formed to capitalize on economic development and infrastructure investment opportunities	Coalition works together to enable focusing funds on best economic projects that benefits all	*Next Generation Corridor Framework associates funding opportunities with a holistic understanding of value on a corridor.*
Market the corridor, prepare resources to position corridor for grants, and develop business plan for corridor	Prepare documents that are accessible for marketing the corridor for private enterprises	*The framework provides a platform to consider impact payoffs and investment resources at all levels of public and private corridor management (not just state DOT cash flows).*

Data

Best Practices in Land-use/Sustainability	Key Advances from State-of-the-Practice to State-of-the-Art	Specification/Target for Next Generation Corridor Framework
I-95/I-85 Corridor: VDOT data sharing/partnerships with INRIX, RITIS, NPMRDS into one performance dashboard	VDOT working with publicly available data to develop dashboard for one-stop-shop data source	Framework offers guidance regarding the level of granularity and consistency for corridor impact intelligence at different levels.
MassDOT/Boston MPO public-facing dashboards for real-time video, traffic, construction	Real-time information available to all public users	Framework demonstrates how data from corridor management partners can be leveraged within 7-D context to support targets for managers at all levels.
I-15 Corridor: Mobility alliance focused on data sharing, truck parking, smart truck parking and weather and incident management	Focus on sharing data with planning community to enable all parties to address issues with same sources	Framework includes practical self-assessments for corridor managers to evaluate and incrementally improve the consistency and effectiveness of their use impact data utilization across corridor systems
UDOT freeway performance website for historical travel times – partner with HERE and Google APS for data.	Historical travel enables planning to analyze what historically has occurred and how to prepare for it	

ACES/ITS

Best Practices in Land-use/Sustainability	Key Advances from State-of-the-Practice to State-of-the-Art	Specification/Target for Next Generation Corridor Framework
I-94 Corridor: Variable speed limits during inclement weather	Use data to reduce speeds to prevent crashes	*Framework offers roles and opportunities to assess the status of corridors with respect to emerging or disruptive technologies.*
ITS Strategic plan – focus on methods for analyzing impacts to roadways and addressing them in real-time	Analyze public transportation, traveler information, traffic, construction, safety, in one place	
I-95/I-85 Corridor: VDOT alternate route or all corridors in state	Work with Waze to program alternate routes instead of using local roads	*Framework is conducive to goal setting at national, regional and local levels for both technological readiness and incremental implementation of technological advances.*
VDOT metrics for incident management as well as ITS to monitor roadways	Instant towing dispatch, time to clear, work zone hours, weather events	
I-45 Corridor: Sustainable connected network in major triangle (Houston, Austin, Dallas, San Antonio)	Proving grounds for autonomous vehicles developed in partnership for state	
I-15 Corridor: Managed Motorways – WFRC speed detectors sense when freeway is failing and increase wait time at on-ramps to prevent total collapse	Use real-time data to automatically adjust signals to reduce congestion	
UDOT Bus Reliability – DSRC communication to give green time to buses if behind schedule	Real-time signals prioritize transit schedules and mode choice	
Public-Private partnership for V21, V2V, V2X applications with AASHTO, FHWA, MPOs.	Developing long-range framework to enable ACES technologies on future travel-demand and infrastructure	

3.10 Corridor and Network Capacity Methodologies and Calculators

Corridor Management often includes strategies and technologies to improve the efficiency of existing vehicle lanes, and also can include alternative modes for increasing the person-trip throughput of corridors. Corridors are also affected by the nature of the background support network. This is a short overview of the NCHRP 08-124 effort which created new methodologies for evaluating corridor and network-level analysis and a description of the accompanying Excel-based calculators.

3.10.1 Freeway Corridor Person-Trip Calculator

Urban freeway corridors often have many features that influence the overall ability to move people and goods. Below are more common (green) and less common or emerging (blue):

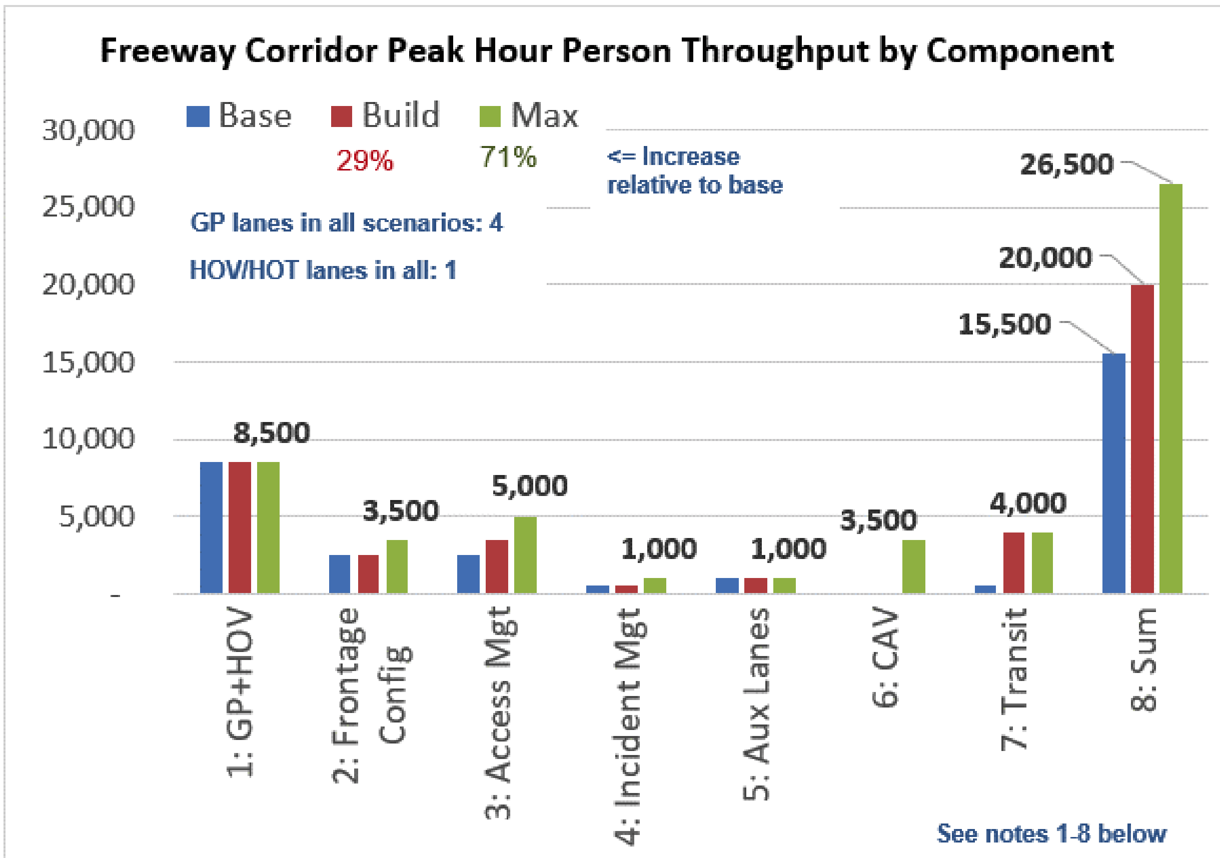
- General-purpose lanes & HOV/HOT lanes
- Auxiliary lanes (for on-ramp/off-ramp weaving)
- Ramp Metering methods and policies
- Congestion Pricing (preventing stop-n-go)
- Frontage roads (one-way or two-way)
- Incident Management Equipment & Policies
- Alternative mode options and associated fares
- Connected and Autonomous Vehicle (CAV)

An Excel calculator (see below) was created to help you determine the overall person-trip capability of a freeway corridor as it stands today, compared to a Build scenario likely to offer higher throughput potential given the same number of overall freeway lanes. In many cases such as ramp metering or congestion pricing, "Build" may not require much actual infrastructure, but instead, require a commitment to manage the system for maximum efficiency. The "Max" scenario represents the maximum, or most efficient, form of the option (which may be politically difficult). Max is used to define 100 on a scale of 1-100, so the user can then see how a base and build compare to this perfect-score scenario. Grey cells are where the user makes changes. The right side of the table tabulates points toward both functional and environmental sustainability.

	Base	Build	Max	Base	Build	Max	Base	Build	Max
Step 1: Basic attributes of the freeway corridor									
Base Auto Occupancy	1.4	1.4	1.4	F.Sust.	F.Sust.	F.Sust.	E.Sust.	E.Sust.	E.Sust.
General purpose lanes, each dir	4	4	4	0	0	0	-1	-1	-1
HOV/HOT Lanes, each dir	1	1	1	1	1	1	1	1	1
HOV Min Occupancy	2	3	4+	0	1	2	0	1	2
Full-length Aux Lane?	Yes	Yes	Yes	1	1	1	0	0	0
Frontage Road Configuration	Two-way, both sides	Two-way, both sides	One-way both sides	0	0	2	0	0	2
Step 2: Base-case and build policies designed to reduce likelihood of overloading freeway									
Ramp Metering Method	No Metering	Traditional, Uncoordinated	Coordinated, Algorithmic	0	1	3	0	0	0
Ramp Metering Policy	No Meters	Up to 4-min	6+, if nec.	0	1	3	0	0	0
Congestion Pricing?	None	Full Fwy, limit $max	Full Fwy, no $Limit	0	3	6	0	3	6
Incident management policy	No program or policy	Arrive Quick, Remove Slow	All Fast: Push, Pull, or Drag	0	1	2	0	0	0
Step 3: Base and build transit situation, and any assumptions about future Connected and Autonomous Vehicle efficiency gains									
Transit, Long Distance	Express Buses	Two transit options	Two transit options	1	4	4	1	4	4
Peak Hour Screenline Ridership	600	1800	1800						
Free/Low Fare Transit?	No	Yes	Yes	0	2	2	0	2	2
CAV Throughput gains (1.0 if no CAV)	1.00	1.00	1.30	0	0	2	0	0	0
			Points, Raw	3	15	28	1	10	16
			Points, 1-100	11	54	100	6	63	100

Access: The Corridor and Network Multimodal Capacity Calculators are available on the National Academies Press website (nap.nationalacademies.org) by searching for *NCHRP Web-Only Document 386: Quantifying the Impacts of Corridor Management*.

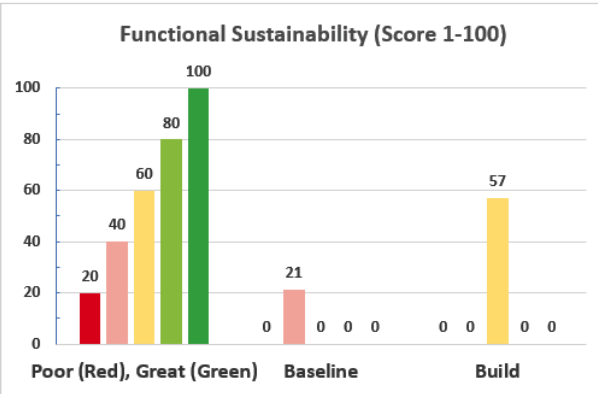
This graphic shows the various components of the corridor's peak hour person-trip throughput. This case evaluates a 10-lane freeway (four general-purpose lanes + 1 HOV/HOT lane, in each direction). Notice in the base case that these lanes contribute about 8,500 person-trips per hour, but the overall corridor can carry 15,500 trips per hour. The additional trips are accomplished using two-way frontage roads, traditional ramp metering (access mgt), typical incident management, auxiliary lanes, and a modest amount of transit.

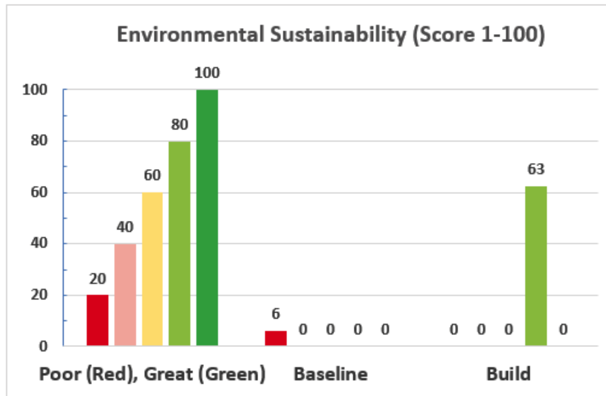


However, there is much more potential for higher person-trip throughput even with the same number of lanes. For example, reconfiguring frontage roads from 2-way to 1-way will boost overall throughput. Modern algorithmic ramp metering and congestion pricing can eliminate stop-n-go, keeping throughput as high as possible. A "push, pull, or drag" policy can minimize the impacts of incidents. More attractive forms of transit, or free/low-fare transit, can attract many more riders (freeing up space in vehicle lanes). Down the road, CAV has the potential to increase lane capacity. In this case, the potential throughput is 26,500 people per hour – 71% higher than today's 15,500. Prioritizing management strategies over more expensive construction strategies can be a good way to make the most of what you have.

3.10.2 Sustainability Scores

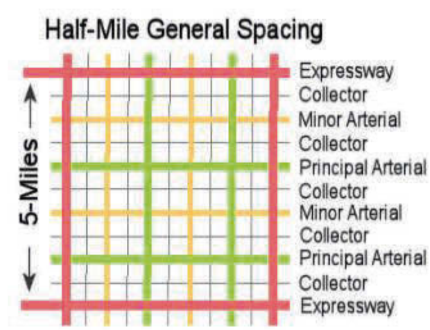
In addition to computing throughput estimates, the tool rates a user's baseline and build scenarios on a scale of 1-100 for functional and environmental sustainability. Anything under 20 is a poor performer relative to its potential, and anything over 80 is getting about all that it could likely get. In this case, the baseline is poor in both forms of sustainability, while the proposed projects and policies for Build make it far more sustainable.





About Sustainability Scores: These charts show how well your base case and build scenarios are performing relative to the Max scenario. Max is by definition 100 points, assuming it were possible to do all things in the corridor that would secure maximum functional and environmental sustainability.

3.10.3 Regional and Study Area Network Analysis



NCHRP Report 917, the Right-sizing Guidebook, features a recommendation first proposed by the Institute of Transportation Engineers that fully developed suburban/urban areas would do well to have an expressway every 5-miles, arterial every 1-mile, and a collector every half-mile. This diagram depicts a "fishnet grid" tile that matches this recommendation.

NCHRP 08-124 recognized that this 5x5 "tile" may be more network than is needed at buildout for locations with wetlands, mountains, or large swaths of large-lot suburbs, and developed patterns for 7x7 and 10x10 tiles as shown below.

Fishnet pattern for 5x5-mile tile, where buildout has little open space and is likely to be heavily suburban, with a fair amount of urban.

Miles from Expwy 1	-	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
Roadway ID	1	2	3	4	5	6	7	8	9	10	Rpt	2	3
Functional Class	E	C	M	C	P	C	M	C	P	C	E	C	...

Expressway/Fwy
Principal Arterial
Minor Arterial
Collector

Fishnet pattern for 7x7-mile tile, where buildout includes significant open space or a great many large-lot neighborhoods

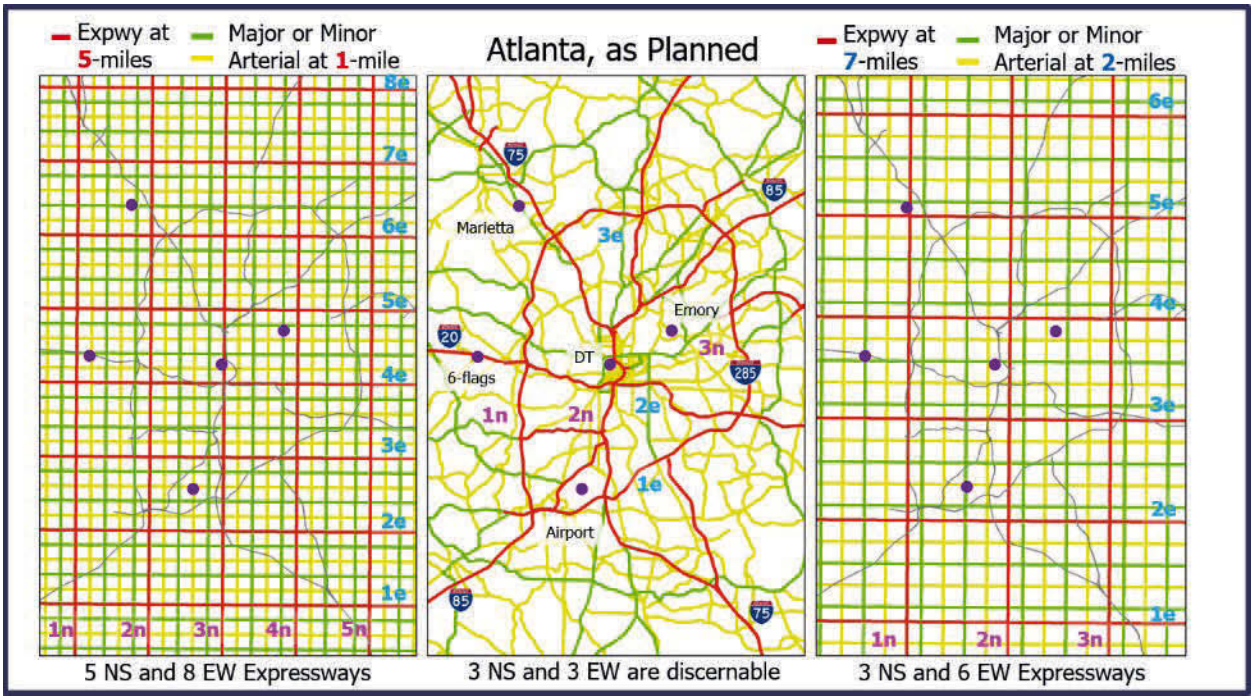
Miles from Expwy 1	-	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0
Roadway ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Rpt	2	3
Functional Class	E	C	P	C	C	M	C	C	P	C	C	M	C	C	E	C	...

Rpt Repeat Pattern

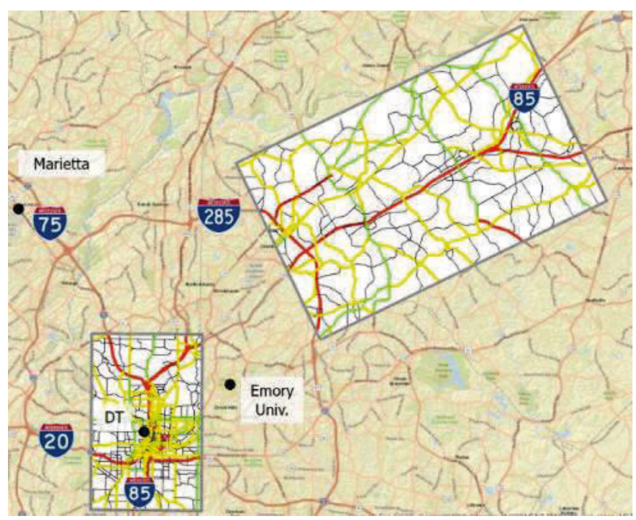
Fishnet pattern for 10x10-mile tile, where buildout includes significant open space or low density (Made for Asheville area)

Miles from Expwy 1	-	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0
Roadway ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Rpt	2	3
Functional Class	E	C	C	M	C	C	P	C	C	M	C	C	P	C	C	M	C	C	P	C	E	C	...

In this graphic, Atlanta is compared to both the 5x5 tiles and 7x7 tiles. In both cases, the existing network appears to be lacking both expressway and arterial corridors. This may be a significant reason why the corridors that do exist are so overwhelmed – there simply aren't enough of them relative to the population that has emerged.



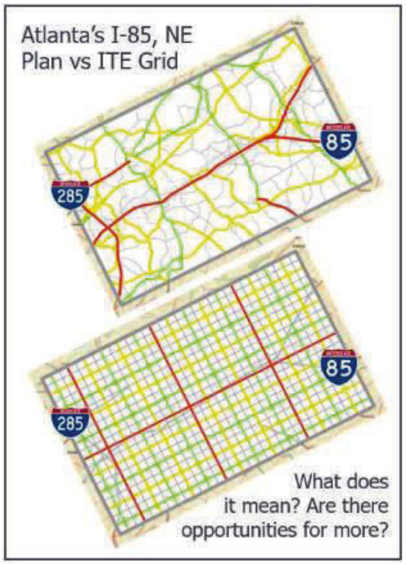
The spreadsheet tool offers analytical means of evaluating both regional and study-area networks to determine adequacy. In the graphic adjacent, there are two study areas: the downtown area, and also the I-85 corridor northeast of downtown.



The next pages show some graphics and calculations, primarily from GIS analysis, that relied on tables in the spreadsheet tool.

Intersections	SqMi	147.0	
	I-85 North		
	Bench	Actual	Pct
Exp X Exp	6	2	33%
Exp X Art	20	10	50%
Art X Art	60	35	58%
Collectors	160	80	50%
Total	246	127	52%

Intersections per Sq Mi.	I-85 North		
	Bench	Actual	Pct
Exp X Exp	0.0	0.0	33%
Exp X Art	0.1	0.1	50%
Art X Art	0.4	0.2	58%
Collectors	1.1	0.5	50%
Total	1.7	0.9	52%



Above is a comparison of how many intersections a highly connected, highly resilient network would have relative to how many it actually has. Actual is only 52% of ideal.

In this visual comparison (left), it is easy to see the over-reliance on just a few corridors. A GIS analysis shows that while actual has fewer miles of expressways than the fishnet grid, the lane miles are higher than in the fishnet. Using tables in this spreadsheet, total peak hour VMT capability was computed for the fishnet grid and for the actual network. Actual expressways have 20% more VMT capability, while everything else has less capability. While the network itself is sparse, overall VMT capability is 95% of what the fishnet grid can support. This suggests that any given road is likely far larger than it would have been in the fishnet scenario, and freeways, in particular, have been super-sized over time, in large part because they are serving local circulation due to an overwhelmed background network.

Lane Miles	SqMi	147.0	
	I-85 North		
	Bench	Actual	Pct
Expressway	264	378	143%
Principal	595	417	70%
Minor	476	251	53%
Collector	614	478	78%
Total	1949	1525	78%

VMT Capability	SqMi	147.0	
	I-85 North		
	Bench	Actual	Pct
Expressway	1,000,000	1,200,000	120%
Principal	500,000	400,000	80%
Minor	400,000	300,000	75%
Collector	200,000	100,000	50%
Total	2,100,000	2,000,000	95%

How does this help corridor management?

Understanding the larger context can help reveal why critical corridors are under pressure. An under-sized background network can lead the user to look outside the immediate corridor for opportunities to enhance connectivity. In rural areas quickly transitioning to suburban, it helps reveal opportunities to work with locals to preserve an adequate background network so that critical corridors never become overwhelmed.

3.11 Supporting Documentation

Playbook: Case Study Critical Content Review Outline and Interview Questions

CORRIDOR AND METRO AREA(S) DESCRIPTION(S)

Broad Corridor Description

1. Primary artery(s)
2. Major metro areas/cities
3. Describe transportation activities in the corridor, what are the modes involved, what are the nodes, volumes, multimodal connections, key generators and other information to describe how people and goods move through the corridor.
4. Does the corridor connect to other key corridors?
5. Describe the metro area arterial/tributary system connecting to the corridor
    a. Grid network?
    b. Spacing of Grid?
    c. Access to freight clusters
    d. Identified intermodal connectors
    e. …
6. Describe the geography and demographics of the corridor (states, metropolitan areas involved, length), Map of the overall corridor and specific metro areas (let's discuss how this gets done).
7. Metro area(s) of focus
    a. Why/how selected?
    b. Small, large urban area
    c. Describe the general land-use paradigm of selected corridor/metro areas:
        i. Urban, suburban, exurb, …
        ii. Residential nodes
        iii. Freight nodes/villages/clusters

Corridor/Metro Area(s) Critical Content Review

General Information

1. Number of MPOs
2. Describe/list stakeholders identified and their roles
3. Names of relevant organizations
4. Do they have established corridor coalitions? If so, how are they used, who participates, what is the governance structure?

Focus Area 1: Definitions of corridors and characteristics

1. Is it apparent how agencies define corridors? If so, what characteristics do they associate with corridors?
2. Do agencies define key local or regional nodes (urban centers, towns, or entire cities) connected by corridors?
3. Do they define key intermodal connections associated with the corridor/area?
4. …

Focus Area 2: Corridor management strategies

1. What type(s) of corridor management activities are in place?
2. What types of plans or programs are involved in corridor management? Is it reflected in regional and state plans, others?
3. Do their plans have established intermediate/corridor planning frameworks? If so, what contextual elements are incorporated? How is it applied?
4. What types of Integrated Corridor Management (ICM) tools are used? What performance measures are used?
5. What type of ITS technology technologies are used?
6. If Intelligent Transportation System (ITS) solutions are used for ICM, what is the level of maturity? Is there a Capability Maturity Measurement done? What information is available?
7. Do the agencies use land-use policy metrics to manage and evaluate performance? If so, which, and how are they used?
8. Do their plans define corridor management? If so, how?
9. Is it apparent whether their plans differentiate management strategies by scope and scale?
10. Do their plans discuss cross-jurisdictional relationships? If so, are other jurisdictions in the corridor employing the same or different strategies?
11. Is it apparent whether corridors are managed from a multimodal perspective? If the corridors are "multimodal" do they mention funding issues/barriers related to strategy implementation?
12. Do their plans discuss project prioritization relative to corridor management?
13. Do their plans discuss corridor planning, project development, and corridor management goals?
14. Reducing congestion levels? If so, how is this accomplished?
15. Supply or demand strategies, or both?
16. Maintain speeds? If so, how is this accomplished?
17. Improve safety? If so, how is this accomplished?
18. Revitalize adjacent land-uses

Focus Area 3: Incorporation of modern mobility- ACES "issues"

1. Is it apparent whether agencies are considering changing technologies?
2. It is apparent how the agencies are considering mobility for people and freight?
3. Are they evaluating corridor for ways in which ACES may change how it operates and performs?
4. Is it apparent whether they have state regulations relative to ACES operations?

Focus Area 4: Methodologies to Assess the Effectiveness of Strategies

1. Are performance measures used to measure corridor activity, if so, which ones and how? Provide examples from document content review.
2. Are life cycle cost analyses used? If so, how are they used in decision making and how are they assessed?
3. Do the agencies use economic impact metrics to manage and evaluate performance? If so, which, and how are they used?
4. Who monitors performance, where is this captured, and how is it used? How is performance reported, displayed and disseminated?
   What analysis tools are used?

Focus Area 5: Data sufficiency and validity

1. How do agencies measure the impacts of CM and ICM (not simply performance but the evaluation of the action of CM/ICM and is it working as intended)? What measures are they using? What types of reports are used to collect and demonstrate the impacts? Where does this information go and how do they adjust?
2. Is it apparent what data is used?
3. How was data collected and used?
4. Do they use purchased data?

INTERVIEWS

Introduction and Background

Purpose of 08-124: Quantifying the Impacts of Corridor Management Research Effort:

Research objective- The objective of this research is to identify key attributes of effective, sustainable "form and function" corridor management, where the functional aspects of a corridor can evolve in harmony with the uses that are formed around it. A major problem, especially in urban arterial corridors, is that corridors focused primarily on moving traffic safely at high speeds have inadvertently contributed to the decay of dependent uses. Research and experience show that, when such decay occurs, both businesses and residents tend to "flee to the fringes," which results in excess spending by public agencies to build and maintain duplicative infrastructure. Therefore, this research will develop new performance measures that show the tradeoffs between managing corridors to sustain the highest and best land-uses and high vehicle throughput, ensuring that corridors function well and remain attractive for development. This research is predicated on the understanding that facilitating the movement of goods and people requires coordinating land-use and transportation-infrastructure decisions at various geographic scales. Corridor management offers an opportunity to coordinate transportation and land-use planning with decision-making among multiple jurisdictions and stakeholders across a range of geographic scales. It requires coordination between state, local, and other agencies that regulate different aspects of corridors such as roadway design, operations, access, land-use and development, property subdivision, utilities, and rights-of-way.

The goal of the case research presented here is to critically evaluate how well current corridor management best practices balance the tradeoffs between community development and regional trade. The case studies will compare (1) the current level of understanding regarding the estimated success of different corridor management strategies, as well as (2) the effectiveness with which studies and other efforts have quantified this impact.

Definition of "corridor"

A corridor should be thought of as more than any one facility. Two analogies have been used, the Nile and its tributaries and a human's circulatory system. For example, geographically, the I-15 "corridor" extends from the ports of So. Cal to Salt Lake and crosses four states. So, I-15 is the Nile River, or the Carotid Artery, through which people and goods flow. Where those people and goods end up is not only dependent on the artery, but on its veins, capillaries, or tributaries, etc. Do the partners manage the Nile and tributaries with the same method(s), or do methods change by scale and complexity, and if so how?

Interview questions

What is your role? How would you describe your role?

1. **Focus Area 1: Definitions of corridors and characteristics**
   a. How do you define a corridor? Is it roadway prism, or larger, a fluid definition?
   b. What are the linkages to the shared workforce, supply chains, or resources using the corridors?
   c. What are the key local or regional nodes (urban centers, towns, or entire cities) connected by corridor?
   d. What are the key modal or inter-modal connections and systems associated with the corridor?
   e. Describe the political or wider policy prerogatives determining a corridor's boundaries.

2. **Focus Area 2: Corridor management strategies**
   a. General strategy questions
      i. How do you define corridor management?
      ii. What is important to each of you in corridor management, and what an optimal outcome for the corridor would be?
      iii. How do you manage performance in corridors? (open-ended)
      iv. How much of your focus is on long interstate corridors vs. shorter urban corridors?
      v. Do the strategies you employ cross-jurisdictional boundaries? If so, are other jurisdictions in the corridor employing the same or different strategies?
      vi. How is performance management being implemented in your organization?
      vii. Are corridors managed from a multimodal perspective?
      viii. If the corridor is "multimodal" have you encountered funding issues/barriers related to strategy implementation? If so, can you briefly describe the nature of these issues? Complete streets, high/low speeds, traffic calming, road diets, ...?
      ix. Does your agency have a formal project prioritization process? If so, what role does it play in corridor management?
      x. Do you think there are "good" workflow connections between long-range planning objectives and project implementation in your agency?
         1. If so, does your agency have formal workflows/frameworks that establish the connections? Can you describe them?
         2. If not, what do you think would help with the connections?
         3. How does your agency use corridor planning?
            a. Programmatic?
            b. Formal framework?
            c. Case by case?
   b. How important are the below goals in your corridor planning, project development, and management strategies?
      i. Reducing congestion levels? If so, how is this accomplished?
      ii. Supply or demand strategies, or both?
      iii. Maintain speeds? If so, how is this accomplished?
      iv. Supply or demand strategies, or both?
      v. Improve safety? If so, how is this accomplished?
      vi. Revitalize adjacent land-uses
      vii. How has your thinking changed based on strategy outcomes?

Supply Strategy Examples

- Capacity additions
- Operational efficiency improvements
  - ITS tools and resources?
- Integrated corridor management (ICM)

Demand Strategy Examples

- Land-use considerations - Degree to which land-use or other non-traditional considerations are used in planning, designing and managing a corridor?
- Allow congestion to build
- Shifting freight to rail, or waterways, or…
- Pricing strategies
- Access management
- Complete streets
- Road diets
- Reduced sprawl development
- Speed- lower or raise
- Peak demand diversion
- Transit, pass programs
- Rideshare
- Business incentives
- Balancing transportation system network utilization

3. **Focus Area 3: Incorporation of modern mobility- ACES "issues"**
   a. What advancements in terms of mobility for people and freight are you employing? What has been most useful?
   b. What types of resources would help, what do you wish you had?
   c. How do you measure performance of these tools and resources?
   d. Are you looking at the corridor for ways in which CAV may change how it operates and performs?
   e. Do state laws and/or local ordinances allow for CAV operations in the corridor?
   f. Where is your agency or organization in terms of CAV awareness? Are you planning for new technologies, testing or incorporating these into your strategies?
   g. How do you think CAV will change your corridor in the future? What do you think will be its impact on land-uses and transportation flows?
4. **Focus Area 4: Methodologies to Assess the Effectiveness of Strategies**
   a. What types of methodologies do you use to assess the effectiveness of the strategies you use for corridor management and or ICM?
   b. What types of analyses do you do?
   c. Travel demand modeling, operations modeling/simulation, BCAs, EIAs, qualitative, …?
   d. What kinds of information do you seek to assess the impacts of the strategies?
   e. How do you report out? To whom? Which agency is the lead and who takes action?
   f. How do you evaluate the CM/ICM program? What feedback loop do you provide and when do you re-evaluate?
   g. What types of ways have you had to adjust your strategies based on the impact analyses? What have you done or decided not to do? Who did you have to work with to adjust? What resources were needed, and did you get them?
5. **Focus Area 5: Data sufficiency and validity**
   a. How do you know your strategies are working?
   b. What types of planning, modeling, data analytics, operational and programming (capital construction) resources or actions do you use to support corridor management strategies?

   c. What type of data does your agency use in your corridor management programs? Do the data sources change based upon the level of complexity and scale?
   d. Which measures of impacts are most useful? Which are least useful? Are there data issues such that measures cannot be used? (Assessing data sufficiency and validity)
   e. What type of reporting regime(s) does your agency follow? Does your data support the regime(s)? Would newer data sources produce more defensible findings? (Assessing data sufficiency and validity – with regard to corridor management)
   f. Has your agency been asked to consider non-traditional performance/impact metrics like economic outcomes, land-use/community outcomes, health, induced demand, sprawl, …? If so, how are they used?

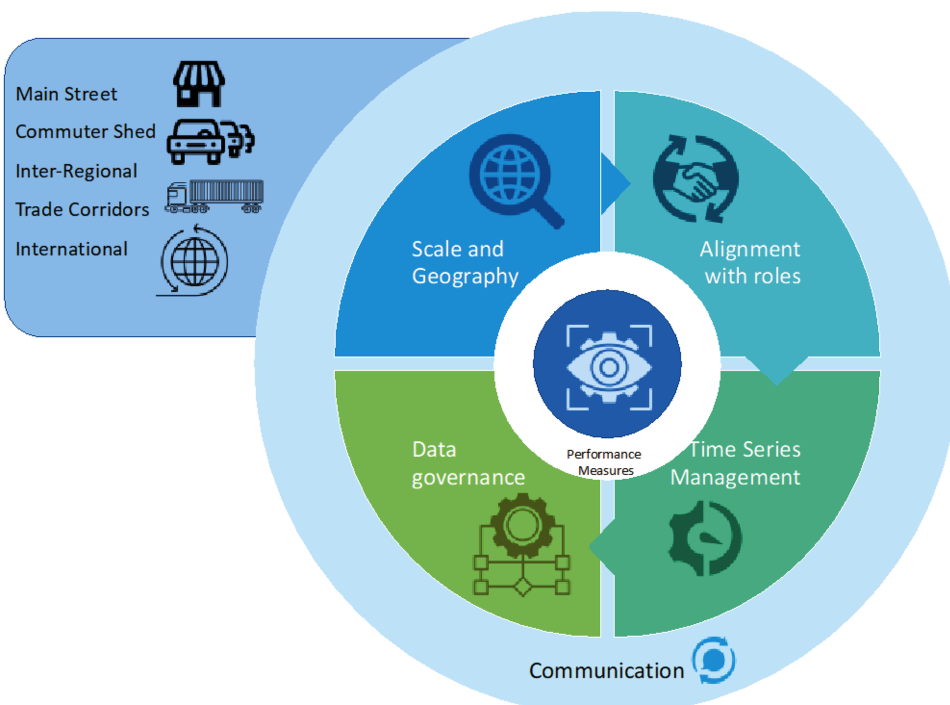
6. Finding?
   a. SWOT – Describe Strengths, Weaknesses, Opportunities and Threats (SWOT) based on:
      i. Focus areas
         1. Corridor definition and characteristics
         2. Corridor management strategies
         3. Modern mobility issues, including CV/AV
         4. Methodologies to assess strategies
         5. Data sufficiency and availability

7. Conclusion
   a. Describe or summarize key findings
      i. Best measures for measuring impacts of CM/ICM.
      ii. Key challenges that exist.
      iii. Findings by type of corridor.
      iv. Recommendations for Next Generation Corridor Framework.

Appendix 4
Corridor Impact Concepts

4.1 Objective and Scope

Appendix 4 offers a conceptual framework for the Playbook for corridor management. It follows (1) an initial literature review (APP 1), (2) a summary of the state of the practice in managing the impacts of corridor management (APP 2) and (3) a body of case research and SWOT analysis of the current corridor impact practices (APP 3). This Next-Generation Corridor Management Concepts report responds to the finding in Appendix 3 that in order to utilize a new impact measurement framework – there are aspects of the corridor management process itself that may be adapted to better focus on long-term impacts. For this reason, the current appendix builds on the Appendix 3 case research to further address those research objectives that pertain to the policy environment in which the corridor management playbook can most optimally be applied.



A stated objective for the Corridor Management Playbook is *"a delineation of the primary components of a corridor management program and how those components address measuring public value and sustainability"*

3. A description and review of current experience, including existing tools and techniques used to measure impacts and implement a corridor management program in support of various planning and management objectives;

4. A matrix or other organizing technique that can be used to classify the variety of corridors as a basis for the framework; and

5. Recommendations for models and/or strategic approaches to measuring impacts (quantitatively and qualitatively) and integrate current practices with potential changes that can occur, taking into account risk and uncertainty in long-term planning and forecasting methods.

The framework and guidelines are intended to supplement FHWA's Integrated Corridor Management (ICM) program which is directed toward transportation system operations and performance on corridors using technology and intelligent transportation systems (ITS). In contrast, this research will focus on transportation system corridor management as a proactive transportation and land-use planning activity with an emphasis on maximizing public value while implementing effective infrastructure investment strategies.

Introduction

Currently, most corridor management efforts focus on improving the flow of goods, services and people along roadways. However, such a focus ignores important interactions between transportation corridors and the areas they serve, particularly when it comes to quality of life concerns, environmental and air quality, economic impacts, and the cost of corridor infrastructure. Classical theory on the evolution of transport networks clearly shows the interaction between transport networks, development, and urban form. Despite this, contemporary practice has been to approach corridor projects as distinct from urban form. This practice has led to spatially linear development patterns along major trade routes, which can end up contributing to urban congestion by concentrating traffic flows on a few links. A major objective of this research is to develop a framework that helps state DOTs and their partners develop corridor management practices that enable and encourage the functional aspects of a corridor to evolve in harmony with the uses that are formed around it. The Playbook and its supporting research offer corridor managers a chance to move away from a paradigm of defining a corridor simply by vehicle throughput, to one that includes notions of highest and best land-uses that attract contextually appropriate development and improve quality of life. The purpose of this appendix is to present foundational ideas for how the corridor management framework can enable transportation agencies and their partners to conceive, establish and implement contextually appropriate corridor management structures.

4.2 Managing Corridors for Impact

As stated at the outset of Appendix 3, corridors can have different scales and geography, and because of that, various degrees of complexity. the characteristics, or context of the corridor. While just looking at the framework will not give one the answer, a framework can guide one through a process that will reveal the contextual nature of the corridor at which point one can begin to make decisions about the management of the corridor. In this sense, a framework can be thought of as an organizational structure, a construct, or an architecture focused on a defined purpose and outcome. Frameworks can be applied to different categories of work where an overall picture is needed. They are used to make conceptual distinctions and organize ideas. Strong conceptual frameworks capture something real and do it in a way that is easy to remember and apply. When talking about frameworks, several words help explain what they do- explore, discover and consider. For example, Appendixes 7 and 8 build on a series of corridor type examples ranging from freight-specific corridors to commuter corridors and use the research findings of Appendix 2 and Appendix 9 to outline key characteristics of those corridors that can help agencies develop their own approach to corridor management.

The Playbook is structured to guide users through a series of decision points that help an agency and its partners navigate and measure corridor management impacts in an unbiased way to establish a contextually based corridor management structure. A framework will help agencies explore, consider issues and discover what is important given the cultural, political and physical realities of a proposed corridor or system of corridors. A framework will help identify key decision points, help the managing entities identify internal constituents, external stakeholders, and external interested parties. A framework will help partners think through how to establish a corridor coalition and develop an appropriate governance structure. A framework will help partners establish a vision for their endeavor, help identify appropriate impact measures, help establish data management practices, and establish monitoring and measuring practices that are appropriate given the corridor management vision and objectives. Lastly, a corridor management framework can help partners think through communication and outreach protocols to help the corridor coalition manage the partnership and communicate with its constituents.

It is important to note that given the nature of what a framework is and is not, Playbook offers a balance between the use of prescriptive and non-prescriptive language. As articulated previously, a framework is not intended to tell a coalition it should measure any particular thing, nor does a framework contain an algorithmic-driven easy button that, when pushed, provides an answer. Appendixes 7 and 8 (and Play 1: Define the Corridor and Its Impact) are offered to enable corridor managers to navigate these questions.

4.3 Decision Points and Attributes

The following sections pinpoint likely decision points and attributes that a managing entity will face when they consider establishing a corridor management structure. Through this discussion, the white paper will inevitably touch on many of the decisions that may be associated with a decision point. Not to belabor the point, pun intended, but the decision points outlined below should in no way be considered the only decision points a managing entity could face, nor are their titles necessarily the most appropriate. But they are representative of the types of decision points agencies will likely face when establishing corridor management structures. Attributes, refer to elements of decisions and reflect the myriad of issues associated with a decision point.

4.3.1 Scale, Geography, and Complexity

Corridors can be thought of as a roadway prism with two end points and in a lot of cases, this is a convenient way to think about them. For purposes of this research effort, however, such a definition only defines one end of the spectrum. The other end of the corridor spectrum could encompass an area that includes many multimodal facilities of different extent; it could span multiple states, the entire country, have an international border, and pass through many different communities and metropolitan areas. Given this range of possibilities, when a managing entity is considering whether to establish a corridor management structure, one of the first questions it must ask itself is one of scale and geography. Appendix 3 introduces the concept of corridor nesting to describe this range of possibilities. The answer to the question will have enormous implications for the complexity of the endeavor, the full extent of which is difficult to anticipate. This white paper outlines a series of decision points and potential guidance and tools for working through them. However, no framework can predict the number of stakeholders that will need to be involved, or how many times a process will need to be followed in order to put all the pieces of a corridor management structure together. Nevertheless, the reader will get a sense of relevant process types and the types of answers a framework can help an agency and its partners to discover.

Corridor Context- Corridor context is a key attribute for consideration by managing entities as they contemplate the parameters of a corridor management program. The context here refers to those aspects of the transportation network and its relationship to communities; its relationship to local, regional, state and inter-state economics; and elements related to quality of life such as health and the natural environment.

As with the framework itself, there isn't a prescribed procedure for going through the process of establishing context. It may be appropriate for the managing entity to conduct the entire process with in-house staff as a way of helping arrive at a decision about scale and geography or helping determine who its stakeholders and potential interested parties may be. It may also be appropriate for the DOT to establish an initial vision for the corridor before engaging its partners. With that said, the managing entity should walk through the context of the discovery process with partners to ensure it has an understanding of their perspectives, and that those perspectives get reflected in the eventual Vision and desired performance outcomes of the corridor management structure.

Community context refers to the nature of a community's built environment, its social and cultural characteristics, its schools, its housing stock, and its disadvantaged populations. Consideration should also be given to whether it is urban, suburban, ex-urban, or rural, whether the land-uses are industrial, commercial, residential, or combinations of the above. Given the scale and geography decision, it may be necessary to establish community context for multiple communities. The point is, when understanding context, it is important for agencies to think broadly and inclusively.

Economic context, in general, refers to the corridor's relationship and contribution to the local, regional, state, and interstate economy.

Transportation context can include features such as facility type, functional classification, freeway and arterial spacing. Other questions can include:

- What is the primary purpose of the corridor (home to work, goods movement, etc.)
- What modes are present?
- What type of transit uses are prevalent?
- Are there significant delay or reliability issues?
- What is the nature of facility ownership and who is responsible for which operational, maintenance and preservation activities?
- What are the accessibility characteristics of the network?
- Are there access management issues?
- Have resiliency measures been considered, planned for, or implemented?
- What operational strategies and ITS initiatives have been adopted?
- …?

Health context can be included with other contextual discussions or kept separate. Keeping the issue separate helps highlight its importance. Questions to consider when discussing the health context of a corridor can include:

- Whether the area is designated as a nonattainment area?

- What transportation strategies are in place or could be implemented to improve air quality?
- Is there transit service to hospitals and primary health care facilities in the area?
- Does the current development and infrastructure pattern accommodate or encourage walking and cycling?
- ...?

Natural context is not necessarily meant to be the same as NEPA and environmental studies, or their mitigation measures, but there will clearly be overlap. The natural context is meant to explore natural features that contribute to the character and aesthetics of the community. Questions to consider include:

- What is the scale of the transportation system and what is its relationship with the surrounding natural features?
- Are there significant natural resources within the corridor area?
- Is there a protected or aesthetically valuable vista or view shed in the planning area?
- Can anticipated long-range mitigation needs for a region be combined to maximize ecological benefits instead of project-by-project mitigation?
- ...?

Establishing a contextual understanding will help the managing entity identify stakeholders and interested parties who will be key to the acceptance and ultimate outcomes of corridor management practices. Stakeholders refer to agencies (local governments for example) that may have management responsibility and metropolitan planning organizations (MPO) that have planning responsibilities within the larger, nested corridor system being considered by the management entity. Representatives from stakeholder agencies and the management agency should include staff with relevant first-hand knowledge, because of their relevant operational knowledge.

Interested parties refer to parties that do not have formal management responsibilities but likely have influence with stakeholders and even the management entity. These groups may include community and neighborhood groups, local business groups, private entities, and others. Interested parties generally include those with a working knowledge of the area being considered as part of a corridor management effort.

It is important to note that how contextual attributes are labeled is not the point. Managing entities may find that some make sense, but others do not, or they may develop their own labels. The point of the exercise is to explore and discover the contextual elements that are foundational to establishing an overall vision, goals, and objectives (Vision) for a corridor. The discussion of context is also intended to help managing entities and ultimately their stakeholders and interested parties explore concepts of value; what is important and why? Such discussions will influence what is measured and over what period, which helps the entity understand its data needs and the time periods required for monitoring and measurement.

4.3.2 Alignment of Roles

Corridor Coalitions (addressed in Play 2: Take Inventory of the Corridor) are critical to a next-generation corridor management concept. Indeed, the literature review and case studies in Appendix 1 and Appendix 3, respectively, illustrate examples of where corridor coalitions have formed and how they are being used. Given these examples and the concepts of corridor management developed in Appendix 3, it is clear there is value in expanding concepts about the role of corridor coalitions in actively managing corridors. The following discussion is divided into five sections- outcomes; governance structure; durability, priority, and flexible consistency; linkages; and triggers and prompts.

Outcomes- A discussion about context provides a mechanism for exploring an enhanced concept of corridor coalitions. Management entities, local governments, and MPOs have varying degrees of jurisdictional authority within a given corridor. Even if a DOT, for example, is only concerned with one facility within a narrow geographic extent, that facility passes through some form of political subdivision that has authority over adjacent land-uses and, in an urbanized area, MPOs have planning responsibility for the facility. The DOT has the option of managing the facility based on its own set of desired outcomes and risks discontent from its partner agencies, or it can engage those agencies, and even its private sector partners, to set up a process that improves joint outcomes.

As discussed in the previous decision point, a discussion of context will guide participants through a structured discussion that helps them think through the myriad of issues that can impact corridor performance. It will likely be important for a managing entity to establish an internal sense of corridor context and develop its understanding of what the Vision for the corridor management system is before engaging its partners. This is especially true if the scale and geography extend beyond local, regional or state boundaries. In such cases, context will necessarily vary across the scale and geography of the corridor system and a managing entity must have a sense of such variance. The reason for this is not to force its perspectives on what is important onto its partners. Rather, the reason is to get a sense of the scale, geography and complexity of the contemplated corridor management system so that when they do engage their potential partners, they are not starting from scratch. Once a managing entity has established its internal sense of context and Vision, it is critical for it to engage its agency partners to begin to understand how they view context, what they value, and what their vision of the corridor system is. Establishing a shared contextual understanding of the corridor system is an iterative process that can take time. How many iterations and how much time it will take is a function of the scale and complexity of a corridor system and the extent to which the managing entity engages interested parties.

A shared contextual understanding leads to a shared vision for the corridor system. From a shared vision, the managing entity and its partners can establish corridor goals, corridor objectives and critically, corridor impact measures. These impact measures form the basis for evaluating corridor improvements and monitoring and measuring corridor performance. Planning is messy and takes time, but if done right, planning shortens implementation times and does improve outcomes. Taking the necessary time early in the process of establishing a corridor management program can help establish enduring coalitions with a shared sense of responsibility for managing corridor outcomes.

Governance Structure- Having jointly evaluated context, established a Vision for the corridor and determined the impact measures, the partners can move to the step of establishing a governance structure that lays out shared responsibilities and memorializes the relationship of the coalition partners. Governance structures can take many forms ranging from simple charters to complex interlocal agreements. Their exact form will depend on the scale and complexity of the corridor system, the number of partners involved in a coalition, potential funding structures for corridor improvements, and individual partner contributions and actions required to meet coalition objectives.

Consider a scenario where the system of corridors includes multiple states and multiple local governments and MPO partners, all of which have some form of jurisdictional authority over sub-components of the larger system. In such a scenario, the interrelationships of the corridor coalition will need to be well thought out and reflected in the governance structure.

Durability, priority, and flexible consistency- Regardless of the technical form a governance structure takes, there are several features that will improve its efficacy. For example, consideration should be given to its durability, the degree to which coalition member leadership gives it priority, and how the structure strikes a balance between consistency and flexibility. Change happens; the leadership of a DOT will change, city councils will change, governing boards will change, and each change imposes risk. Risks can range from disagreements with the Vision and performance objectives of the corridor coalition, to the very existence of the corridor coalition itself. These risks point to the importance of how the coalition was formed. An inclusive process, where the partners feel their issues were considered, where the governance structure was well thought out, can serve as a hedge against changing administrations. A well-thought-out vision, governance structure and partnership can also help overcome pressures to respond to short-term crises whose solutions may hinder long-term objectives. A strong history of inclusion with stakeholders and interested parties, a detailed analysis of how the coalition arrived at its decisions about the why, what, and how of its purpose will create a structure that is durable, has priority within the coalition partner organizations and is flexibility consistent.

Linkages- Coalition partners should undertake an analysis to understand program linkages. Linkages in this sense are the processes by which the coalition will understand, and the means by which they will tie the various elements of the corridor system together into a comprehensive structure that supports the Vision and performance objectives of a larger system. In a complex system of corridors, it's very likely coalition partners will have some form of jurisdictional authority over sub-corridors, or processes. Given that, there needs to be thought given to how each component fits with the larger whole. How do components contribute to an overall vision and how to aggregate measures of performance, so they support system objectives and performance outcomes?

Triggers and Prompts- Another less weighty, but still important consideration for any governance mechanism is the concept of trigger points or prompts. They serve multiple purposes like determining how often coalition partners meet to review performance objectives, establishing “event types” that could warrant a corridor coalition to meet, or when to reevaluate corridor performance objectives.

4.3.3 Times Series Management

The title of this decision point may not be intuitive at first glance. Yet, it aptly describes the challenge of measuring performance when considering a broad set of non-traditional impact measures. In a traditional approach, measuring performance is a relatively simple process that typically doesn’t require a decision-making structure. Traditional measures focus on a variant of congestion and reliability that can be easily measured and relative time frames are consistent. However, the findings in Appendixes 1-3 demonstrate that significant other characteristics of value can change and be measured over time in the era of big data.

Characteristics of Value- When a managing entity brings in new partners, they will likely bring along with them new concepts of value. Measures of congestion, reliability, pavement condition, and safety are important to a lot of DOTs, but they may be of less concern to a municipality focused on creating a walkable, mixed-use center. A freight carrier may be concerned about congestion, but it may also be concerned about having real-time information about road conditions, adequate truck parking along interstates, and adequate vehicle staging near warehouses and distribution centers. Questions to consider may include:

- How will a managing entity incorporate these new concepts of value into its regular decision-making processes?
- If a DOT, as a managing entity, incorporates non-traditional measures of value in one case, what does that mean for its regular decision-making processes?
- How do new notions of value play into funding?
- What will be the federal response if delay on an interstate takes a back seat to a transit first strategy?
- How will a managing entity measure return on investment?
- Do new ideas of value enhance, or detract from potential private sector investment in corridor improvements?
- How will a corridor coalition weight a traditional, easily quantifiable concept of value against a non-traditional, difficult or impossible to quantify concept of value?

This is all to say new conceptions of value will have different characteristics than current ones and managing entities should be prepared to address these eventualities with their potential coalition partners and their governing boards.

Impact Measures- New concepts of value may be difficult to quantify. Take quality of life for example, or improving non-project-related wetlands? How would a corridor coalition quantify the value of a mountain range that provides recreation opportunities for millions of residents? One answer may simply be that some non-traditional measures are too difficult to quantify. If that is the case, then having a well-thought-out structure will help the coalition partners address such questions regarding the veracity of the coalition, its vision, and its performance objectives.

With that said, monitoring and measuring are critical to the long-term success of a corridor coalition and there are impact measures for non-traditional concepts of value that can be measured. The 7-D framework, or D-Variables, is one such example. Appendix 5 suggests evaluation techniques, supported by Appendixes 10 and 11 offering empirical findings and practical methods for the use of D-variables in corridor management as a way to address this issue. This explicit treatment of D-variables offers a promising approach to assessing travel demand that has not been statistically validated prior to the empirical work shown in Appendix 11. More than 200 studies have sought to explain household travel outcomes such as trip frequencies, mode choices, trip distances, or overall vehicle miles traveled using one or more of the D variables.

A central challenge for a corridor coalition is balancing the need for efficient vehicle movement with local quality of life and economic development. Just as land-use planning seeks to arrange industrial, commercial, services, and residential activities to ensure the highest and best uses, corridor planning should seek to utilize infrastructure to support these highest and best uses. However, in many cases, the work of corridor management has fallen largely to state transportation agencies, which tend to be less focused on economic development and land-use development. The purpose of a next-generation corridor management framework is to help managing entities and their coalition partners identify innovative corridor management practices that allow for a two-way interaction between land-use decisions and economic development at scale, while also improving travel times, delay, fuel consumption and emissions, and the reliability and predictability of travel within corridors themselves.

4.3.4 Data Availability, Standardization, and Organization

One of the biggest advances in understanding transportation corridor operations in the past decade has been the advent of real-time or near real-time GPS vehicle tracking information. The trucking industry, for example, was one of the early adopters of in-vehicle GPS tracking systems. While trucking company customers appreciated the information GPS systems could supply about shipment location and status in real-time, trucking companies also saw a new data source that could be used for improving operational efficiency.

State DOTs are now implementing their own data acquisitions and data management strategies by deploying in-house data-gathering technologies and purchasing data on the open marker from aggregators. All of this is an attempt to understand better what is happening in real-time on their networks. At the same time, DOTs are using new concepts of value and real-time data sources to transform their project prioritization processes from issue-focused processes to outcome-focused processes. This is encouraging given the next-generation corridor management practices envisioned with this research effort.

Next-generation corridor management structures, with new concepts of value, and new impact measures will require corridor coalitions to think through their data needs:

- Is data available?
- Will the coalition have to purchase the data?
- Will partners be required to share their data?
- How will the data be managed and stored?
- How will the coalition ensure the accuracy and validity of the data?

4.3.5 Communication, Coordination and Partnering

While communication, coordination, and partnering (CC&P) are bringing up the rear in this outline, the reader will recognize that each of the preceding decision points requires a sophisticated approach to CC&P. CC&P, is a unified concept, is at the heart of every successful endeavor. Constructing a corridor coalition charged with managing a complex system of corridors, over a wide-ranging geographic area, and establishing a unified Vision and impact measures is no easy task. Frameworks can outline technical paths for how to think through a series of complex decision points, but if considerable thought is not given to the CC&P element, or if the CC&P component is poorly executed, successful outcomes will be difficult to achieve.

Some of the issues that coalition partners should think through include:

- How will initial communications with potential partners be made?
- How will coalition meetings be facilitated?
- How will the coalition engage their federal partners?
- How will internal agency relationships be managed; will the executive leadership of coalition partners meet; if so, what is their role?
- How will community outreach be managed?
- What type of communication materials will be needed for each of the above interactions?

The above is just a sampling of the CC&P issues, but the questions point to the array of considerations a coalition should think through as it sets up a corridor management structure.

4.4 New Challenges

New challenges facing DOTs and their partners, all with far-reaching implications, include disruptive technologies, pandemics, and climate change. Connected and autonomous vehicle adoption has the potential to significantly change how performance is understood in future corridor management efforts. The 2020-2021 COVID-19 pandemic has disrupted global supply chains and it is likely there will be some manufacturing brought back to the US, with huge economic and transportation network implications. And lastly, climate change is already affecting US and international transportation networks and communities.

These new challenges highlight the value of frameworks. As addressed at the outset of this appendix, a framework is not an algorithmic construct with an easy button that gives the user an answer. Rather, a framework helps agencies think through unknowns and arrive at an approach to managing them. At the risk of oversimplifying, a framework is analogous to teaching a person to fish, rather than giving that person a fish. A comprehensive and flexible framework can help agencies develop an approach to managing complex systems of corridors as well as address unknowns like disruptive technologies, pandemics, and climate change.

Appendix 5
Steps and Methods

Implementing the Steps and Methods

In order to carry out the programmatic steps and apply the methods offered in the prior section, corridor managers require an implementation “apparatus” for managing corridors This implementation apparatus is understood as a holistic structure for how managers can navigate the entire process of corridor management.

5.1 Integrating Programmatic Steps and Methods into a Holistic Process of Impact Based Corridor Management

When implementing the Playbook, Managers can benefit from a structure by which a corridor management program may be more explicitly tied to selecting impact methods and metrics. The recommended plays of the playbook lead managers in the use of new methods, tools, and frameworks through critical junctures in the corridor management process. These junctures can generally be understood as:

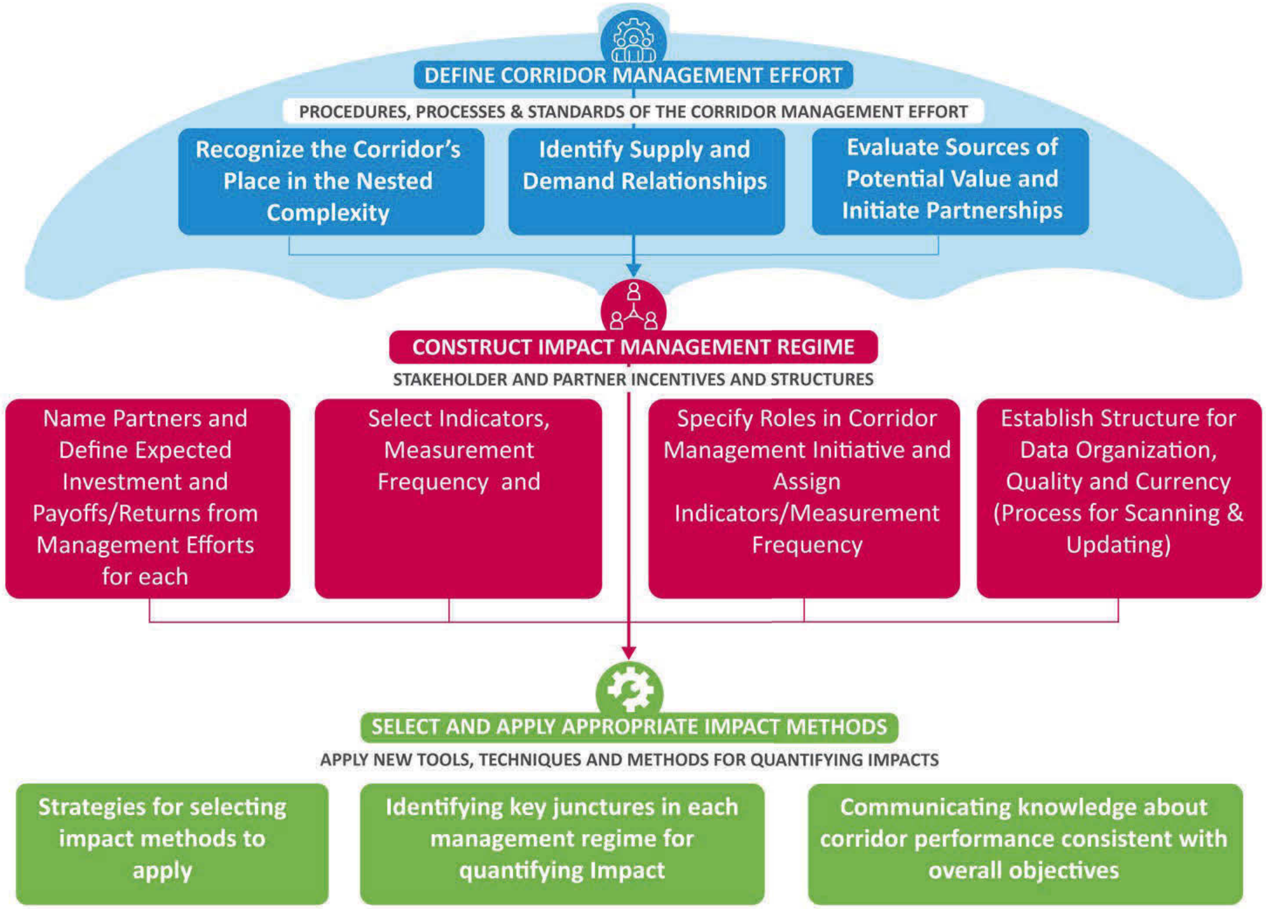
(1)Defining the Corridor Management Effort

(2) Constructing the Corridor Management Regime; and

(3) Selecting and Implementing Quantitative Impact Measurement Techniques

While these junctures must occur sequentially (at least at the outset); it is understood that once a corridor management effort is underway – they can be revisited. For example, the management effort must first initially be defined before a management regime can be constructed, or measures selected or implemented – however, this is not to say that the definition of the effort and its scope may not then be periodically re-visited as circumstances, technologies, needs, and other circumstances change over time. The three junctures above can be understood as a practical “mapping” of the practice of impact-based corridor management opportunities and informed by the Playbook.

The figure below illustrates an overall structure for a corridor management process that implements the programmatic steps, engages key partners and decisions, selects data and metrics and applies corridor impact methods available to support the Playbook.



5.1.1 Defining the Corridor Management Effort

Initially Defining the Management Effort: Defining the corridor management effort is understood to begin with (1) conceptualizing the need for a corridor management effort, (2) enlisting and engaging an initial set of partner agencies or champions with enough interest in the corridor and its intended outcomes to (3) initiate formal partnerships and agreements to initiate a process of constructing a corridor management regime. As shown in the figure above – it is this over-arching "umbrella" definitional process that largely encapsulates, and appoints the structure within which both the regime of implementing corridor management and the understanding of quantified impacts is given its purpose and meaning.

Currency of Defining the Management Effort: A finding of the Playbook research has been that the definition of a corridor management effort must also include intervals and triggers for partners to re-assess the definition of the effort. The Playbook and its supporting Appendixes 7 and 8 provide instruction both for how to arrive at the initial definition, but also how, when, and with what process to adapt, evolve and revise the definition of the effort over time (in Plays 5 and 7).

Using the Playbooks Research in Defining the Management Effort: The appendixes accompanying the Playbook provide significant guidance for navigating the corridor management process. Appendix 2 documents different contexts for corridor management efforts, the evolution of a host of corridor management paradigms, unique challenges for managing suburban arterials, and existing and emerging frameworks for monitoring corridor performance. The case research in Appendix 3 introduces a structure of nested complexity of corridor systems and sub-systems, which are a component of the Playbooks' recommendations for defining corridor management efforts. This report also gives a detailed discussion of how the scope of corridor management efforts can be defined to address a mix of supply and demand-side performance management strategies as well as the selection of partners with the appropriate combination of authority, resources, and information to define a successful corridor management effort. Appendix 4 provides specific programmatic steps associated with defining (and re-defining) a corridor management effort, practical check lists and discussion questions for partners considering initiating the definition of a corridor management effort, and guidance for practical ways to align roles in defining a corridor management effort. The table below summarizes how the appendixes and research behind the playbook can inform corridor managers at each key juncture of the corridor management process:

DEFINING THE CORRIDOR MANAGEMENT EFFORT: USE OF PLAYBOOK RESOURCES	
Corridor Management Playbook Resources	Key Actions in Defining Corridor Management Effort
Appendix 2: Synthesis of Documented Practice in Quantifying Corridor Impacts & Review/Inventory of Performance Indicators and Data sources	• Evaluating the Context of the Corridor Management Need • Selecting an Appropriate Paradigm of Corridor Management • Consider Unique Challenges if managing Suburban arterials • Incorporate Accepted Principles for Monitoring Performance
Appendix 3 : Corridor Impact Measurement SWOT	• Identify the Corridor's Role in Nested/Complex Systems or sub-systems • Identify supply and demand-side partners & considerations • Engage partners with appropriate authority, resources & information
Appendix 4: Next-Generation Corridor Management Concepts	• Follow Programmatic Steps of Defining the Effort • Apply Check-Lists to Ensure Key issues are Addressed • Consider Roles to Align in Corridor Management Regime
Appendixes 6, 7 and 8	• Use typologies and corridor characteristics to pinpoint stakeholders, select performance metrics and evaluation methods

5.1.2 Construct the Impact Management Regime

Initially Constructing the Impact Management Regime: Constructing the impact management regime is understood to begin with (1) naming the partners and defining their expected investment and associated payoffs in the effort (2) selecting indicators appropriate for the available investment in the management effort and anticipated payoffs (3) specify the roles of partners in both managing the corridor in quantifying/communicating the impacts of the management effectiveness and (4) establishing a structure to ensure the structure, currency, and quality of data and analysis of impacts through the life of the corridor management effort.

Currency of the Impact Management Regime: A finding of the Playbook research has been that the corridor management regimes require regular intervals and triggers for partners to re-assess the key constructs by which the effort is managed. The Playbook offers instruction both for how to arrive at management regime, but also how, when, and with what process to adapt, evolve and revise the definition of the effort over time.

Using Playbook Resources in Constructing the Management Regime: Appendix 1 provides a catalog of existing corridor performance indicators that can be selected as part of a corridor management regime and defines their supportive data sources, and also catalogs existing methods (and documented resources on their implementation). Appendix 2 documents specific unique challenges for establishing management regimes in suburban arterial areas (where matters of jurisdiction, growth management, and establishing buy-in from key partners are central). Appendix 3 introduces principles for identifying junctures for how to structure a corridor management regime to use ex-ante, benchmarking, and ex-post evaluations of impacts (as well as considerations for relating a modeled understanding of corridor performance to observed, based on a rich body of case research). Appendix 3 also discusses the integration of roles to combine authority, resources, and information and to support data sufficiency, standards, objectivity, and currency in a corridor management regime. Appendix 4: *Next-Generation Corridor Management Concepts* provides a focus on aligning roles within a corridor management regime with practical policy and discussion questions for groups looking at the structure of any given corridor management regime. The table below summarizes how specific appendixes and supporting Playbook resources can be used in constructing a corridor management regime.

CONSTRUCTING THE CORRIDOR MANAGEMENT REGIME: USE OF PLAYBOOK RESOURCES	
Corridor Management Playbook Resources	Key Actions in Constructing the Corridor Management Regime
Appendix 1: Literature Review	• Select Performance Areas, Impact Metrics and Data Sources • Consider proven/long-standing methods to quantify impact
Appendix 2: Synthesis of Documented Practice in Quantifying Corridor Impacts & Review/Inventory of Performance Indicators and Data sources	• Consider Unique Challenges if managing Suburban arterials
Appendix 3: Corridor Impact Measurement SWOT	• Consider key points in time for forecasting, benchmarking, or ex-post evaluation of management impacts • Define appropriate roles, incentives, and accountability in the management process (and how they can be updated with time) • Establish data and technical resources for quantifying and communicating needs, impacts, and changes in the corridor over time.
Appendix 4: Next-Generation Corridor Management Concepts	• Create specific policy obligations, commitments, and contributions for members • Establish ongoing practices (who will meet, when, for what purposes) • Establish reporting protocols
Appendixes 6, 7 and 8	• Use typologies and corridor characteristics to pinpoint stakeholders, select performance metrics and evaluation methods

5.1.3 Select and Apply Quantitative Impact Methods

Initially Constructing the Impact Methodology: Constructing the quantitative impact methodology is understood largely in terms of establishing a protocol to utilize and report data, analysis, and tracking of the impacts of the corridor management effort to (1) support the ongoing investment of partners interested in particular outcomes, (2) identify key changes in the corridor management needs or opportunities that may warrant revising the definition or management regime and (3) evaluate the effectiveness of the strategies included in the management regime. The Playbook and its supporting appendixes (1) offer strategies for selecting impact methods to apply (APP 7 and APP 8), (2) identify which methods fit best at the key junctures identified in the corridor management regime, and (3) Communicating knowledge about corridor performance consistent with overall objectives (of both the definitional rationale for managing the corridor as well as the specific objectives of the management regime).

Currency of the Impact Methodology: A finding of the Playbook research has been that corridor management impact methodologies can and often do overlook key changes in technology, demographics, political economy, and other circumstances affecting a corridor management life cycle. For this reason, while it is likely that some methods can be offered to monitor (and trigger) corridor managers to re-assess the definition and regime of the management effort – in many cases it will be the members themselves, who through less quantitative processes; may need to re-assess the currency of the impact methodology.

Use of Playbook Resources for Quantifying the Impacts of Corridor Management: Appendix 1 provides a catalog of existing corridor performance indicators that can be selected as part of a corridor management regime and defines their supportive data sources, and also catalogs existing methods (and documented resources on their implementation). Appendix 2 documents an extensive range of existing frameworks for quantifying the performance of corridors with respect to different types of management tactics – citing specific data sources and procedures for each as well as the current status of how widely such data and methods have been applied to date. The case research in Appendix 3 describes how specific methods of ex-post, ex-ante, and benchmarking have been applied in specific corridor management efforts – and offers recommendations about their use in specific next-generation efforts supported by the Playbook. Appendix 3 also provides examples of how different types of data are currently used in specific management efforts. The first two sections of this Appendix 5 offer detailed examples of new/cutting edge techniques that corridor managers can select for inclusion in customized next-generation corridor management methodology; giving specific data sources, step-by-step procedures, examples of applications to practical corridor contexts, and likely take-aways from each.

SELECTING AND APPLYING METRICS: USE OF PLAYBOOK RESOURCES	
Corridor Management Playbook Resources	Key Actions in Selecting and Applying Metrics
Appendix 1: Literature Review	• Select Performance Areas, Impact Metrics and Data Sources • Consider proven/long-standing methods to quantify impact
Appendix 2: Synthesis of Documented Practice in Quantifying Corridor Impacts & Review/Inventory of Performance Indicators and Data sources	• Apply established principles and frameworks for monitoring corridor performance
Appendix 3: Corridor Impact Measurement SWOT	• Specify corridor-specific method for ex-ante, benchmarking, or ex-post quantification and reporting of impacts over time • Specify the sources and uses of corridor-specific data elements, their acquisition and maintenance, and how they are to be used in the corridor management process.
Appendix 4: Next-Generation Corridor Management Concepts	• Select or combine methods that meet the needs of the corridor management regime and can be achieved consistently with available data and technology/expertise
Appendixes 6, 7 and 8	• Use typologies and corridor characteristics to pinpoint stakeholders, select performance metrics and evaluation methods

5.2 Next Generation Corridor Management

The corridor management playbook seeks to delineate the primary components of a corridor management program and how those components address measuring public value and sustainability. In an era of big data, the next generation of corridor management efforts can emphasize corridor management as a proactive transportation and land-use planning activity with an emphasis on maximizing public value while implementing effective infrastructure investment strategies. Doing so requires both programmatic steps for when and how to measure corridor impacts, as well as practical methods for quantifying impacts with resources available to most agencies or coalitions.

This Appendix introduces a set of foundational programmatic and policy concepts for corridor management to serve as the basis of programmatic steps, program components, and contextual guidance within which it will offer a new generation ofdata protocols, quantification methods, and reporting protocols for corridor management impact benchmarking, evaluation and decision making. Accordingly, this appendix provides programmatic steps, policy considerations, and implementation concerns for users of the playbook.

5.2.1 Managing Corridors for Impact

A central challenge for a corridor coalition is balancing the need for efficient vehicle movement withlocal quality of life and economic development. Just as land-use planning seeks to arrange industrial, commercial, services, and residential activities to ensure the highest and best uses, corridor planning should seek to utilize infrastructure to support these highest and best uses. However, in many cases, the work of corridor management has fallen largely to state transportation agencies, which tend to be less focused on economic development and land-use development. The purpose of a next-generation corridor management framework is to help managing entities and their coalition partners identify innovative corridor management practices that allow for a two-way interaction between land-use decisions and economic development at scale, while also improving travel times, delay, fuel consumption and emissions, and the reliability and predictability of travel within corridors themselves.

A core finding of the *Corridor Impact Measurement SWOT Analysis* was that corridors are managedat different scales (national, regional, local) with different levels of corridor management activities involving local, regional, inter-regional and national agencies and partnerships. The report offered the *Nested Scanning* approach as a way of pinpointing specific corridor management efforts withinthe context of corridor systems and sub-systems. Based on these findings, Figure 3 in Play #1 offers a practical structure for entities to assess structure corridor management efforts in such a way as to be able to use a new generation of methods and tools to incorporate wider impact considerations and quantitative methods as recommended for use in the Playbook. Each of the 5- steps invites corridor managers to consider key questions regarding the corridor management process.

Key programmatic steps in this framework for corridor management require the practitioner to address five essential questions regarding any given corridor management process. These include addressing five central questions:

- **Step 1: What is the realistic scale, geography, and complexity of the intended corridorimpact?**
- **Step 2: What are the roles of key entities in the corridor management process?**
- **Step 3: How are impacts to be understood over time, and at what junctures?**
- **Step 4: What are the data and technical resources needed or available to assess impact?**
- **Step 5: How, when, and to who are corridor impacts to be communicated?**

The 5- step approach to managing corridors for impact recognizes that corridor managers seeking to apply widerimpact measures in corridor management must have a process for identifying and evaluating their own corridor management efforts within the larger web ofcorridor and system performance. Evolution from simply observing existing practices to offering an actionable framework entails guiding corridor managers through key questions related to the corridor management activity. The figure to the right offers an over-arching view of programmatic components of a corridor management process that can be structured to support the application of wider impact measures of the type presented in the following section to support the implementation of the Playbook.

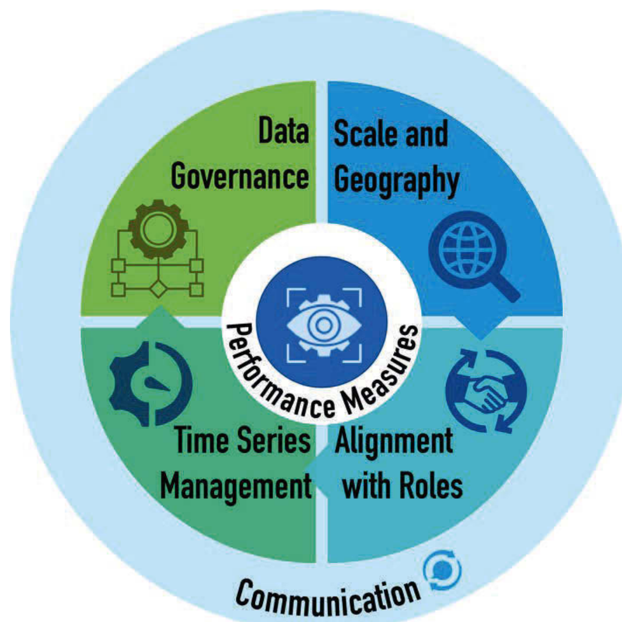


Table 1 provides a summary of the proposed next-generation framework for corridor impact analysis. The table is intended to be included in the final guidebook as a synoptic self-assessment tool that will help practitioners to navigate through the impact-driven elements of the corridor management process and its key decision points, identifying their place in the nested scan of different corridor types, and select and apply "recipes" of corridor impact metrics, displays and benchmarks which may enhance the overall understanding of impact opportunities and objectives.

Table 1 Summary of Next-Generation Framework

Corridor Management Impact Framework				
What is Important				
Purpose	How does one establish a corridor management structure? (Vision and Objectiv			
Goals	How will one know they've arrived?			
Impact Measures	What will be monitored and how will performance be measured?			
Color *Key*	*Why*	*Who*	*What*	*How*
Framework	Why do we care? Who needs to help? What is required to get there?			

The Framework		
Decision Points	Attributes	Recipes
What is the nature of the corridor to be managed? **Scale and geography**	• Define Corridor- scale & geography • Context of the corridor • Complexity- scale, geography & context	Local, regional, state, intra-, inter- Transportation, Community/Land-use, Safety, Health, Economic, Operations, Maintenance, Equity/Diversity, Natural Resources, Congestion, Accessibility
	• Corridor stakeholders	Local Gov, MPO & DOT
	• Interested parties	Public, private, ...
Corridor vision, goals, objectives, and impact measures		
What is the role of each partner in meeting the vision? **Alignment with roles**	• Managing entity • Stakeholders • Interested parties	Role & authority managing entity Roles of stakeholders Roles of interested parties
	• Corridor context • Vision, goals objective, & measures	Establish w/ partners- breadcrumbs... Supply, demand, or both?
	• Governance Mechanism • Interrelationships	Agreement type- charter, ILA ... Attributes- durability, priority
What performance is measured and monitored? **Times series management**	• Value & weighting of impact measures • Monitoring and measuring • Data standardization & analysis • Distinguish causation & forecast • Linkages	Based on context & discussion of value Short, medium, or long-term measurement? Baseline to build scenarios How the pieces fit together, between organizations/measures
	• Prompts & triggers	Why and when to consider?
Data governance and organization	• Availability & cost	At different scales of analysis
	• Sources of data & granularity	Storage
	• Qualitative	How to use and measure?
	• Governance	Storage, auditing, ...
Communications	• Federal relations	Impact on Federal PMs? After actions
	• Public relations	How and when to engage?

5.2.2 Guidance for Implementing Programmatic Steps, Policy Considerations, and Implementation Concerns

In applying the framework, the managing entity should walk through the context of the discovery process with partners to ensure it has an understanding of their perspectives, and that those perspectives get reflected in the eventual Vision and desired performance outcomes of the corridor management structure.

Establishing corridor contextual understanding (community, economic, health, natural) is important. The discussion of context is also intended to help managing entities and ultimately their stakeholders and interested parties explore concepts of value; what is important and why? A shared contextual understanding leads to a shared vision for the corridor system. From a shared vision, themanaging entity and its partners can establish corridor goals, corridor objectives, and, critically, corridor impact measures. These impact measures form the basis for evaluating corridor improvements and monitoring and measuring corridor performance.

Establishing a shared contextual understanding of the corridor system is an iterative process that can take time. How many iterations and how much time it will take is a function of the scale and complexity of a corridor system and the extent to which the managing entity engages interested parties. Establishing a contextual understanding will help the managing entity identify stakeholders and interested parties who will be key to the acceptance and ultimate outcomes of corridor management practices. Stakeholders refer to agencies (local governments, for example) that may have management responsibility and metropolitan planning organizations (MPO) that have planning responsibilities within the larger, nested corridor system being considered by the management entity.

Having jointly evaluated context, established a Vision for the corridor, and determined the impact measures, the partners can move to the step of establishing a governance structure that lays out shared responsibilities and memorializes the relationship of the coalition partners. Governance structures can take many forms ranging from simple charters to complex interlocal agreements. Their exact form will depend on the scale and complexity of the corridor system, the number of partners involved in a coalition, potential funding structures for corridor improvements, and individual partner contributions and actions required to meet coalition objectives. Consideration should be given to its durability, the degree to which coalition member leadership gives it priority, and how the structure strikes a balance between consistency and flexibility. A well-thought-out vision, governance structure, and partnership can also help overcome pressures to respond to short-term crises whose solutions may hinder long-term objectives. A strong history of inclusion with stakeholders and interested parties, a detailed analysis of how the coalition arrived at its decisions about the why, what, and how of its purpose will create a structure that is durable, has priority within the coalition partner organization.

When a managing entity brings in new partners, they will likely bring along with them new conceptsof value. Measures of congestion, reliability, pavement condition, and safety are important to a lot of DOTs, but they may be of less concern to a municipality focused on creating a walkable, mixed-use center. A freight carrier may be concerned about congestion, but it may also be concerned about having real-time information about road conditions, adequate truck parking along interstates, and adequate vehicle staging near warehouses and distribution centers.

5.2.3 Time Series Management

Determining what will be measured is important, but effective performance management also requires determining when to measure, both for establishing a baseline and for future iterations of calculating the performance measurement. This, in turn, is dependent on the time between measurement periods, and what prompts/triggers/defines those periods. In addition to temporal granularity, spatial granularity is an issue—what units of aggregation will be used? Zip codes? TrafficAnalysis Zones? Census Tracts? Establishing rigor in performance management data collection and analysis to ensure comparability of metrics between time periods, and assessing the ongoing availability and cost of data over time. Data from a novel source may not be available ten years into the future. Long-time series also raises the issue of data storage and auditing: How will the data be kept and maintained over time? The latter is especially important regarding the ability to check forecasts against actual data when the forecast period arrives. Traditional measures focus on a variant of congestion and reliability. It is understood how to measure them; the data to do so is readily available, and relative time frames are consistent. New measures often lack these virtues, making them difficult to implement.

5.2.4 Communication

All elements in this corridor management framework require communication: 1) establishing scale/geography to analysis; 2) alignment with roles; 3) time series management, and 4) data governance. Communication is required not only between partners but also in communicating thefindings of the framework to stakeholder partners' own constituents. When and how to engage in public relations regarding the corridor is a topic deserving consideration.

5.2.5 Emerging Challenges and Innovative Solutions

New challenges facing DOTs and their partners, all with far-reaching implications, include disruptive technologies, pandemics, and climate change. Autonomous, Connected, Electric, and Shared (ACES)vehicles have the potential to turn everything currently understood about transportation network planning, project development, operations, and funding on its head. The current COVID-19 pandemic has disrupted global supply chains, highlighting their lack of resiliency, and it is likely there will be some manufacturing brought back to the US, with huge economic and transportation network implications. And lastly, climate change is already affecting US and international transportation networks and communities.

One of the biggest advances in understanding transportation corridor operations in the past decadehas been the advent of real-time or near real-time GPS vehicle tracking information. The trucking industry, for example, was one of the early adopters of in-vehicle GPS tracking systems. While trucking company customers appreciated the information GPS systems could supply about shipment location and status in real-time, trucking companies also saw a new data source that could be used for improving operational efficiency.

State DOTs are now implementing their own data acquisitions and data management strategies by deploying in-house data-gathering technologies and purchasing data on the open market from aggregators. All of this is an attempt to understand better what is happening in real-time on their networks. At the same time, DOTs are using new concepts of value and real-time data sources to transform their project prioritization processes from issue-focused processes to outcome-focused processes.

Examples of Successful Practices & New Impact

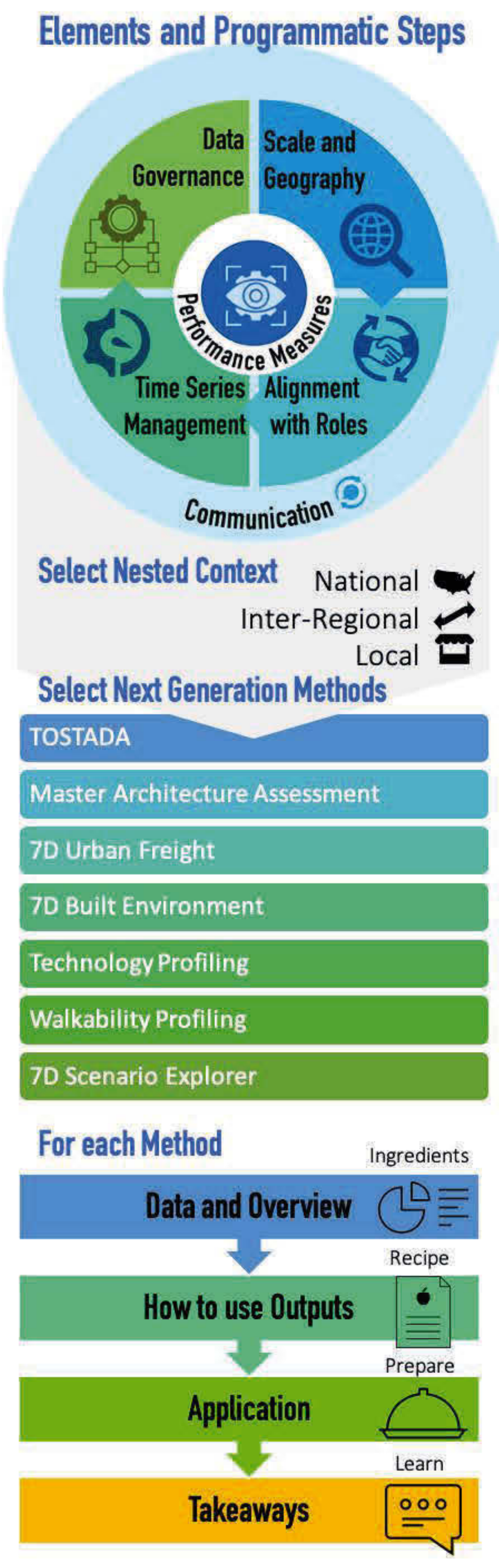


Exhibit 7 Interim Report Overview

Methods & Procedures

This section of the appendix is intended to satisfythe objectives of the research pertaining to identifying data sources, procedures, and promising new practices for quantifying impacts within the context of a wider framework. It is understood that input data, procedures, results, and typical applications of new typesof corridor impact methodologies will only improve the state of the practice if linked to the key elements and programmatic steps described in the prior chapter. For this reason, the figure to the left demonstrates how the programmatic steps can enable corridor managers to define the scope of corridor management efforts, select an appropriate nested context (based on the four elements shown in the top circle); and based on those determinations, select from a host of quantitative methods to frame, evaluate, benchmark and track the impacts of corridor management decisions.

While Appendix 3 extensively documented examples of both successful practices as well as gaps in practice; the focus of the current chapter is on new successful practices deriving from the state of the art in literature but not yet applied to corridors. Proposed new method for quantifying corridor management impacts are presented as "recipes" by which practitioners can operationalize the plays of the playbook in practical, step by step ways. Like all recipes, the next-generation practices include the key elements of (1) data inputs (ingredients), (2) practical steps to assess impacts (procedures), (3) advice on validating andcommunicating results and (4) practical suggestions about how and where the method can be useful to corridor managers.

The practices in this appendix focus largely on managing corridors for impact within the wider land-use/transportation/economic system, going beyond the typical engineering measures. While intended to supplement FHWA's Integrated Corridor Management (ICM) program (which is directed toward transportation system operations and performance on corridors using technology and ITS), the following methods focus on transportationsystem corridor management as a proactive transportation and land-use planning activity with an emphasis on maximizing public value while implementing effective infrastructure investment strategies. There is one practice suggested relating to technology, primarily from the standpoint of applying technology within the focus of practical management objectives. This section includes a summary of potential practices including a review of known and anticipated issues, information required, how to acquire that information, and relevant take-aways.

Exhibit 8 shows a summary of the Next Generation Methods and Tools that will be described in thesections that follow. The corridor management issue addressed highlights the problem and a shortsummary of the solution.

5.3 Infrastructure Impact: TOSTADA & Holistically Managingthe Corridor Infrastructure

Appendix 12 highlights the importance and process for developing a spatial environment for quantifying the impacts of corridor management. This section describes the opportunity for an organization interested in performing corridor management (e.g., state agency, Metropolitan Planning Organization [MPO]) to use the TOol usingSTAcked DAta (TOSTADA) to measure and evaluate the impacts of corridor management.TOSTADA was developed by the Texas A&M Transportation Institute (TTI) to visualize and prioritize corridor performance based on aggregated data by highway segment (1).

Method/Tool	Corridor Management Issue Addressed:
TOol using STAcked DAta (TOSTADA)	**Problem:** Corridor performance is typically considered in terms of disaggregate measures without considering the relationship between measure.
	Summary of Solution: Symbolize and map geodata, then use transparent layering to permit correlations between different metrics.

TOSTADA can be used at the outset of a corridor management planning effort to understand base-level, existing conditions. It can then be reused asvarious corridor management treatments or plan implementations are completed to visualize and assess impacts.

Some of the key benefits of using TOSTADA to measure the impact of corridor management strategies are:

- Reliance on available public data such as mobility, safety, and economic datasets usedubiquitously among public agencies.
- Use of standard, in-house analytical resources that most public agencies already use such asExcel and ArcGIS tools.
- Common sense approach and straightforward mathematical calculations to create oneindex that represents multiple data layers to show comprehensive performance of a corridor.

Named for the regional dish that layers ingredients, TOSTADA is used to layer datasets to understand performance in a combined way instead of considering each performance areaseparately (see Figure 1). TOSTADA is useful to transportation decision-makers by showing a range of different types of indicators such as congestion, safety, pavement condition, bridge condition, and truck commodity value information on one coordinated map. Each of the performance factors can be weighted to createan index that demonstrates the overall performance of a particular segment of the highway. The weighting allows stakeholders and decision-makers flexibility to prioritize indicators that are most important to them and to balance weights depending on the goals and objectives they are trying to achieve in their corridor management efforts. In

this way, TOSTADA provides a combined metric, offering an objective, data-based foundation from which transportation officials can make decisions, as well as assess the impact of completed projects or operational treatments as part of Transportation System Managementand Operations (TSMO) approaches (1).

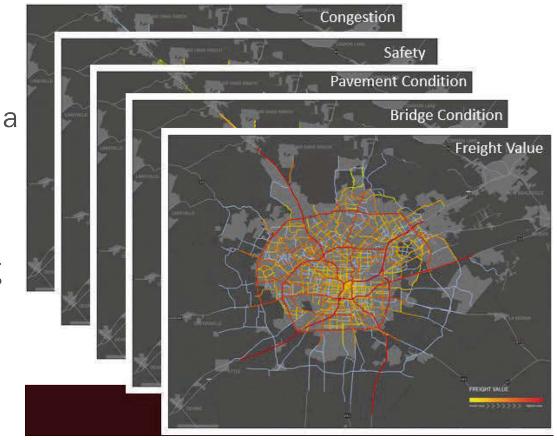


Figure 2: Example of TOSTADA mapping layers. Source: Texas A&M TransportationInstitute (TTI) (2014).

5.3.1 Data and Overview of Procedure

TOSTADA was previously designed and demonstrated with some common data layers in mind.

These types of layers are important information that public agencies generally seek in their performance programs. They are readily available and are beneficial layers for assessing base conditions, impacts, and investments. There are dozens of possible data layersthat could be included and each of the layers listed above could be further broken into more refined components. For example, the congestion layer couldhave peak-period delay, weekend delay, and reliabilitylayers in addition to an overall delay per mile layer.

Data Inputs:

TOSTADA typically includes data layers with the following information:

- Congestion
- Safety
- Asset condition (Bridge and Pavement)
- Economic Value
- Freight Value

TOSTADA layers the performance data using geographic information system (GIS) tools to provide consistent information on topics of interest in one view. TOSTADA relies on data conflated to the highway network segments for a corridor. Each segment has performance calculations for the various data layers included. For example, each segment could have congestion and pavement results. Then, these results could be turned into an index between zero and one and have a weighting applied to each segment. The outputs could then be visualized in color-coded data maps to show the combined performance for each segment of a corridor.

5.3.2 Considering Data Layers

It is important to use a range of interrelated data layers when looking at a corridor because, together, they help to paint a holistic picture of performance. This relationship is described through the following examples of data layers.

Congestion: The addition of a congestion data layer with a safety layer helps to more effectively pinpoint the cause of some safety issues. Congestion sometimes causes safety problems, and in some cases, safety problems lead to congestion. An example of how congestion and safety are tied together is when strategies for reducing traffic congestion improve driver safety by decreasing the opportunity for rear-end crashes.

Safety: Safety is a top goal for transportation systems, and safety information can be divided into two major factors: crash frequency and crash severity. Minimizing both of these elements is important, and the corridor management process must recognize that there are many interrelated factors that ultimately lead to crashes. Safety is related to congestion, as described above. It is also associated with asset conditions in that hazardous pavement or bridge conditions present safety hazards, which are a major cause of concern and usually drive the prioritization of roadway investments.

Pavement Condition: Pavement condition is tied to safety in that higher quality pavement gives drivers better traction and control of their vehicle. Pavement condition is also an important safety factor during precipitation and other weather conditions. Pavement ride quality can be improved by smoother roads, which improve driver satisfaction and safety.

Freight Value: Tracking the value of commodities in trucks on roadways provides decision-makerswith a quantifiable means of understanding the economic impact of one road segment relative to another when determining investments. A road transporting more commodity value may have more economic significance than another, and, thus, for agencies with constrained capital programs, be prioritized for limited funding to help economic conditions.

Economic Value: Understanding economic value is helpful when considering the impacts of investments or management decisions in a corridor. Congestion is related to economic value in that delay adds a cost to people and goods in wasted time and fuel.

These are just a few examples of the relationship among data layers. While any one data layer can be considered independently, looking at them together helps to assess the corridor as a whole andidentify the segments based on the combinations of relationships in order to better understand what worked, what did not, or what could work in terms of corridor management.

5.3.3 Mapping and Indexing Data

TOSTADA's purpose is to help illustrate the ramifications and policy effects of corridor management comprehensively. Therefore, by mapping layers together in one application so that all information for a given corridor is viewed together, TOSTADA is an important resource for decision-makers to identify problem locations and assess solutions. Mapping the data layers together and using the underlying data to create a score or index is useful to see performance throughout the corridor andeven rank segments along the roadways.

The TOSTADA model uses GIS tools to demonstrate the individual map layers and can allow the information to be viewed through color-coded maps. Each map color scale shows performance or condition scaled from poor condition (low performance) to good condition (high performance). The color display changes between map layers and shows a variety of factor-specific elements.

The underlying data can then be indexed into one composite score or index. Each data layer results in its own index. For example, congestion may be reflected as Delay per Mile (DPM), resulting in number of hours, while a ratio-type index such as pavement quality may be one or less depending on the measure. It is necessary to rescale these performance indicators in order to build a composite score. This is done by scaling the individual layer indicators to a range between zero and one. Then, an agency can add a weighting and prioritize the scaled indices from one data layer or several data layers depending on their goals and objectives.

5.3.4 Data Inputs

The following provides examples of the types of performance measures a corridor management agency might want to consider when using TOSTADA. These were created as part of a proof of concept TOSTADA development for the Maryland Department of Transportation (MDOT) (2).

Congestion

The congestion layer uses measures such as the Travel Time Index or DPM. The Travel Time Index isa ratio of the travel time during the peak period to the time required to make the same trip at free-flow speeds. DPM is weighted by vehicle volumes and normalized by mile. Congestion levels on the road segments in the corridor can be compared on a scale of good to bad. Looking at this layer alone allows one to find the most congested segments within a corridor (Figure 3). The annual congestion costs can also be computed to provide an indication of the costliest segments along a corridor based on hours of delay (Figure 4).

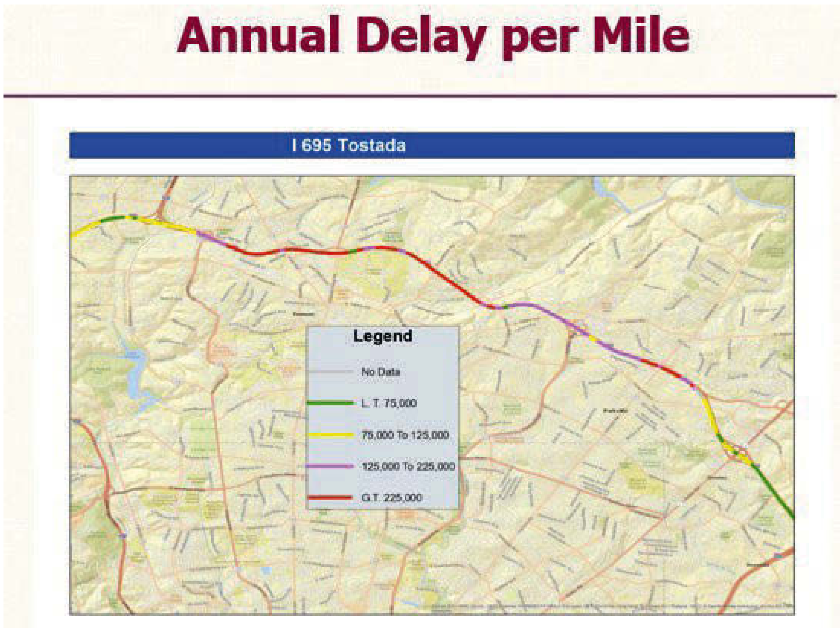


Figure 3: Congestion, Annual Delay per Mile Example.

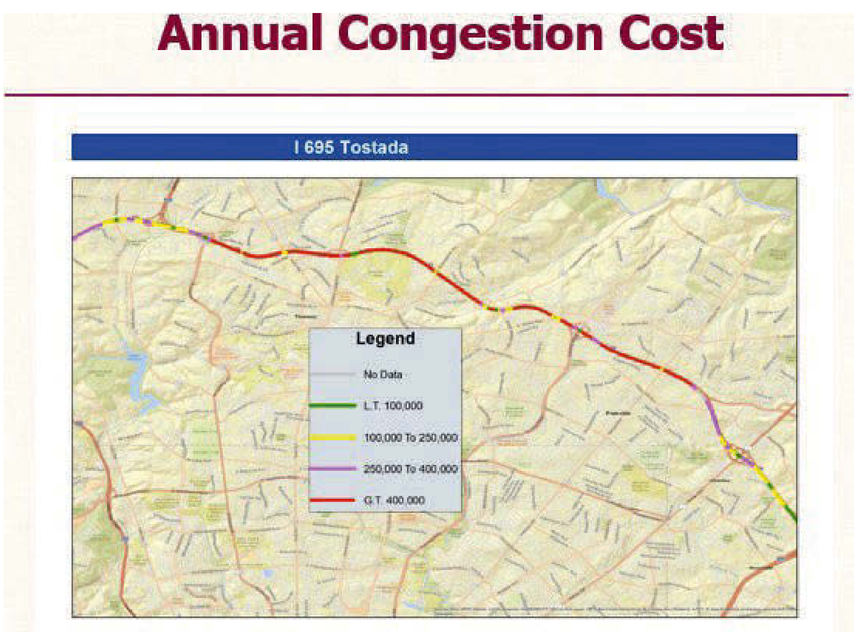


Figure 4: Congestion, Annual Congestion Cost Example.

Safety

The safety layer might focus on crashes such as injuries and fatalities for all traffic and commercialcrashes. It could also include property-damage-only (PDO) crashes. This allows for the comparison ofcrashes or other safety indicators by segments of the corridor to identify the worst performing sections. Examples of PDO and injury crash data are shown in Figure 5 and Figure 6.

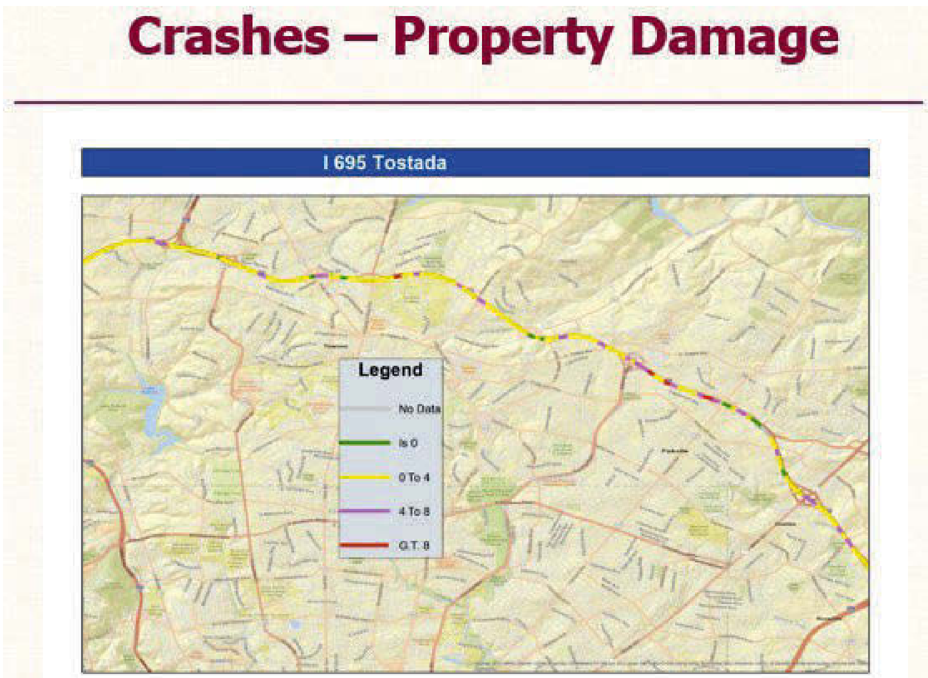


Figure 5: Safety, Crashes - Property Damage Example.

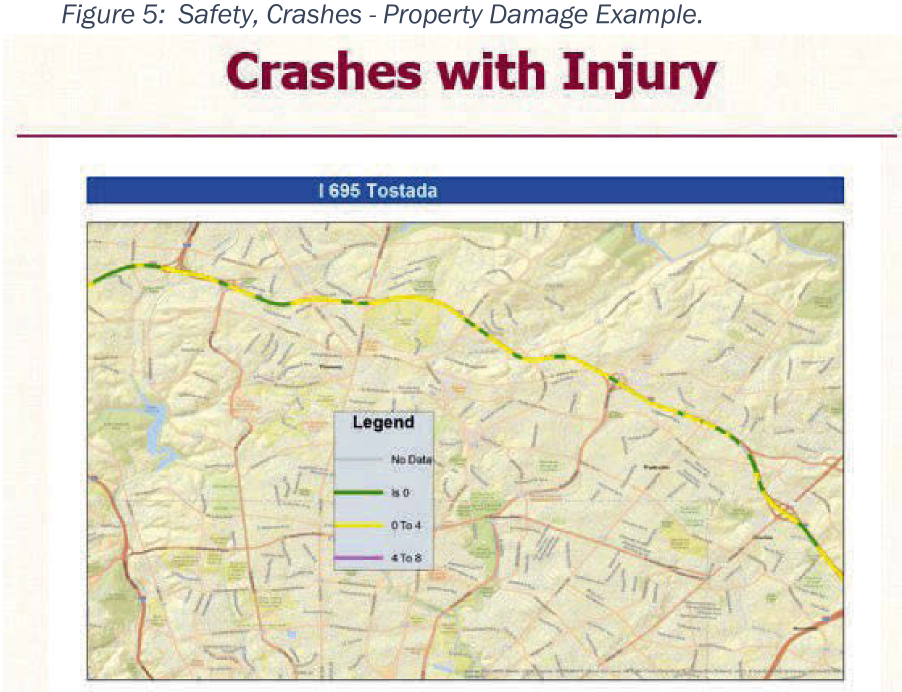


Figure 6: Safety, Crashes with Injury Example.

Pavement Condition

An important asset measure to consider is pavement condition. A pavement condition layer could use a state's grading scale and International Roughness Index (IRI) for pavement quality. This is information states collect and submit to the Federal Highway Administration (FHWA), so it is generally available, especially for state agencies. Measured alone for a corridor, the corridor segments can be ranked based on the IRI or other scale used to see the sections of the corridor in greater need of repair. An example of IRI is shown in Figure 7.

Another important asset indicator is bridge condition. This data layer uses bridge deck condition data for the worst condition rating within a road segment. The rationale for using the worst condition rating on a segment is that the performance of the entire segment is "only as good as itsweakest bridge." An example of bridge condition is shown in Figure 8.

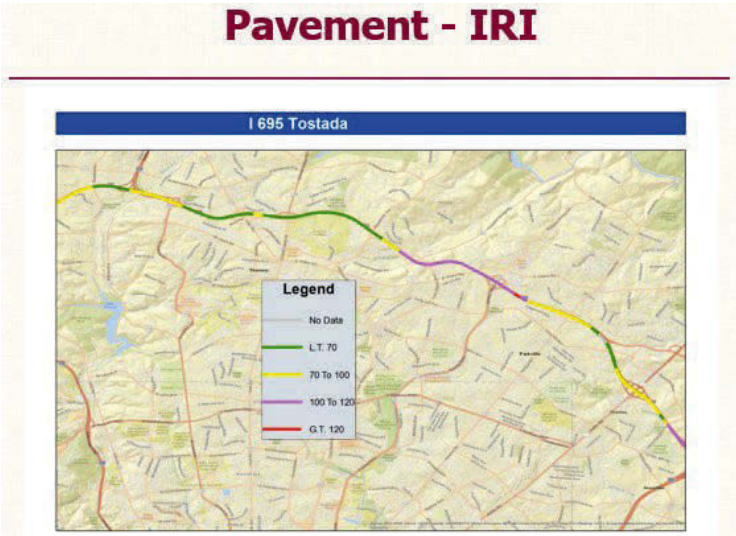


Figure 7: Pavement Condition, IRI Example.

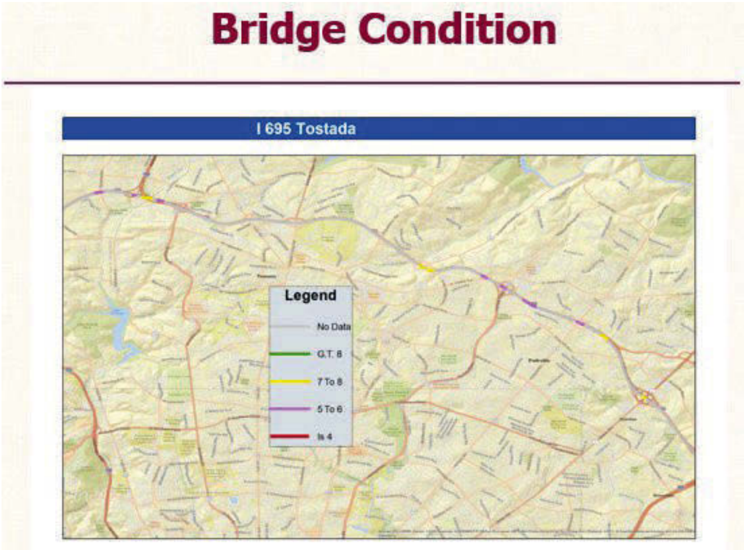


Figure 8: Bridge Condition Example.

Freight Value

Corridor management agencies may be focused on freight movement and want to include a freight value. A freight value layer can illustrate the dollar value of truck commodities carried on road segments estimated using a combination of national and state sources. Truck Volumes (Figure 9) and the FHWA Freight Analysis Framework (FAF) can be used to estimate freight value in a region orstate for the corridor. Figure 10 shows the data used to create a freight value of annual truck commodity value. It relied on corridor truck volume and was combined with FAF information to develop a freight value indicator shown as annual truck commodity value.

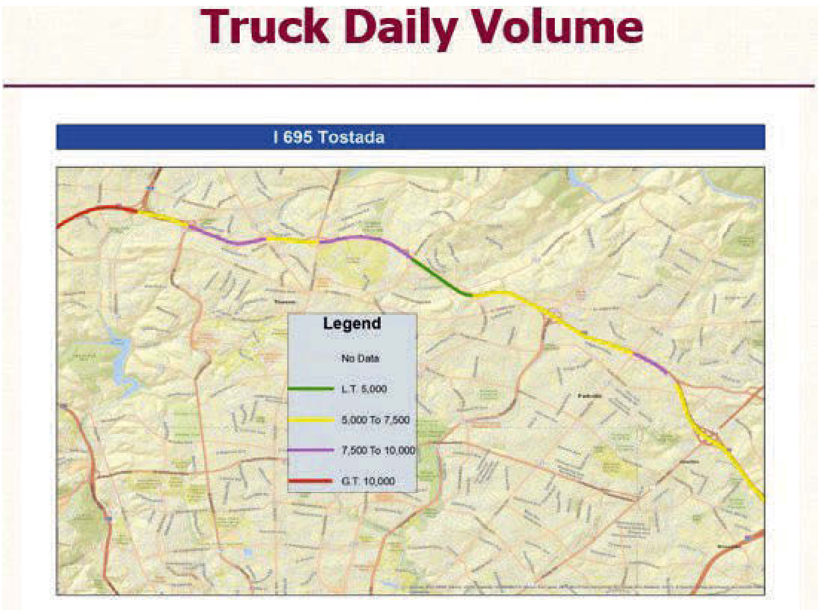


Figure 9: Freight, Truck Daily Volume Example.

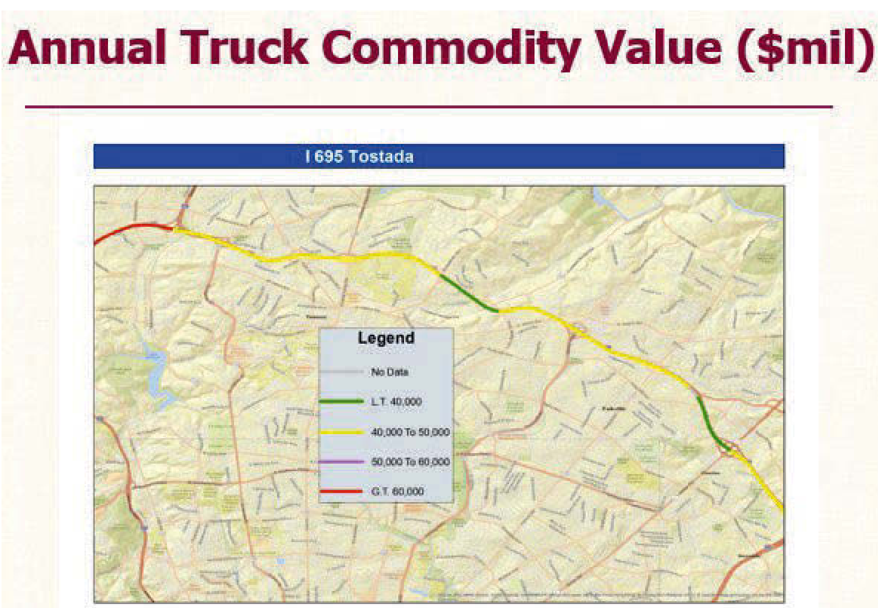


Figure 10: Freight, Annual Truck Commodity Value ($mil) Example.

Economic Value

Another important consideration is the economic value of a corridor. A corridor management agency may want to develop a measure to capture this and see how it changes after corridor treatments, especially if the goal is economic development- or freight-related. To do this, some simple calculations such as using a ratio of metropolitan to state Gross Domestic Product (GDP)could be used.

5.3.5 Process

TOSTADA was named due to the tool's similarity to the way a tostada dish is prepared. A tostada layers many different food ingredients such as vegetables, meat, cheese, and others on top of a tortilla so that as you bite into it, you experience all of the various ingredients and flavors in eachbit. Similarly, TTI created TOSTADA because it helps to understand a variety of project factors in one "visual bite."

For example, a TOSTADA analysis would take each of the individual performance indicators for bridge condition, congestion, freight value, and pavement condition in Figure 11 and combine it intoone map that represents all four indicators. Figure 11 is an archived example for US-281 just north of Loop-1604 in San Antonio, Texas, and shows the map of the location along with performance maps for bridge condition, congestion, freight value, pavement condition, and crash risk.

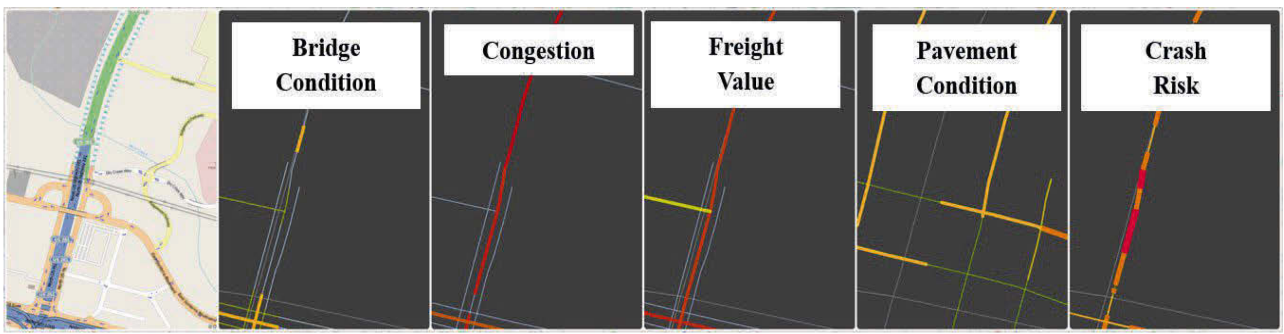


Figure 11: Example of different indicator maps that would be layered in TOSTADA.

In this example, congestion, safety, and freight value have high factor scores. This is shown where segments are colored red. This means that this location, in the past, experienced congestion, had a history of crashes, and had a significant amount of freight movement. The pavement and bridge conditions have average scores, as shown with the segments colored yellow or green. TOSTADA takes all five of these indicators, or however many indicators an agency would want to include and creates one map to illustrate overall performance.

5.3.6 Outputs

The TOSTADA stacked data report produces maps of individual data layers on one coordinated map for a chosen road link. An index is also created to show the combined performance metric for the road segment.

This index of TOSTADA elements –the TOSTADA BITE (**B**asic **I**n**TE**gration) – is a composite that combines indices for data layers in a standardized way. Weights can vary depending on the specific uses of BITE. For example, users may use equal weights for all layers, or freely choose the weight ofeach index to quantify a comprehensive, prioritized set of conditions and performance information for the road network.

Through the maps and TOSTADA BITE, transportation officials may find it easier to:

- Identify transportation problems along a given roadway segment in a corridor;
- Communicate benefits or impacts across multiple assets or performance measures;
- Justify projects that are selected for investment and dollars applied to funding categories;
- Show the effects of treatments on future conditions/performance; and
- Estimate the benefits versus costs of projects in a corridor.

Corridor management agencies can use TOSTADA in two phases. The first phase of TOSTADA involves visualizing the data with maps, making comparisons and assessments, and identifying areas of multiple benefits or competing interests. The second phase entails project prioritization and selection by understanding system-wide impacts.

5.3.7 Application Case Example

The following example applies TOSTADA to the I-45 Corridor in Texas from Galveston to Dallas. Forthis example, only data were collected for the following four data layers for each highway segmentalong the corridor:

1. **Freight commodity value**: This value is based on FAF to apply a value for commodities thatare flowing on that corridor, and estimated based on roadway type (e.g., interstate, freeway, or arterial).
2. **Congestion:** DPM is a defensible, industry-tested, and -approved measure of congestion level weighted by volume of traffic and normalized by mileage.
3. **Economic Value**: This is the value of GDP in the county where the highway segment islocated in relation to the state's GDP.
4. **Pavement**: This is a score of the pavement quality along the corridor, which helps to provide a sense of asset condition.

A value was assigned for the four layers above for each segment of the Texas highway on I-45. These values were then scaled from smallest (zero) to largest (one) to compare across the layersappropriately. Then, a base index was developed to show what the index is with all four categories weighted the same (25 percent). This base score is intended to compare other scenarios where the weighting has been changed. Finally, three more scenarios were developed to show the corridor's performance when each category is weighted higher than the others. While these scenarios may not reflect real-world use cases, they are useful to demonstrate how drastically performance results change when the weighting of the individual layers changes.

For this example, the base and three alternative scenarios were generated as follows:

1. **Scenario One – Base:** Base Index, all measures equally weighted.
2. **Scenario Two – Freight Value and DPM Focus:** Freight Value and DPM are weighted each at40 percent while Economic Value and Pavement are each weighted at 10 percent.
3. **Scenario Three – Economic Value and Pavement Focus:** Economic Value and Pavement are weighted at 40 percent while Freight Value and DPM are weighted at 10 percent.
4. **Scenario Four – DPM (Congestion) Focus:** The measure of congestion (DPM) is weighted inthis scenario at 70 percent while Freight Value, Economic Value, and Pavement are all 10 percent.

5.3.8 Results

Figure 12 through Figure 15 show the maps for each of the four scenarios. Each map shows the index based on the scenario described above. Based on the weighting, the results change, but on each map, there are some common segments where performance is lowest. This is generally south of the Houston region toward Galveston for all scenarios. In Scenario One (Figure 8) and Scenario Three (Figure 10), low performance is identified in the middle to north of the corridor.

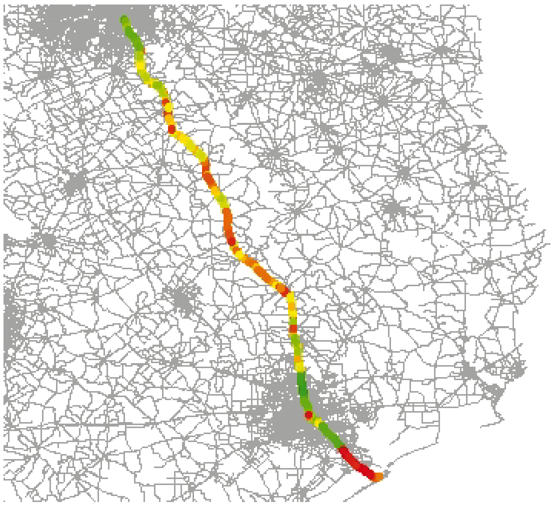


Figure 12: Scenario One, Base Index for I-45 Corridor.

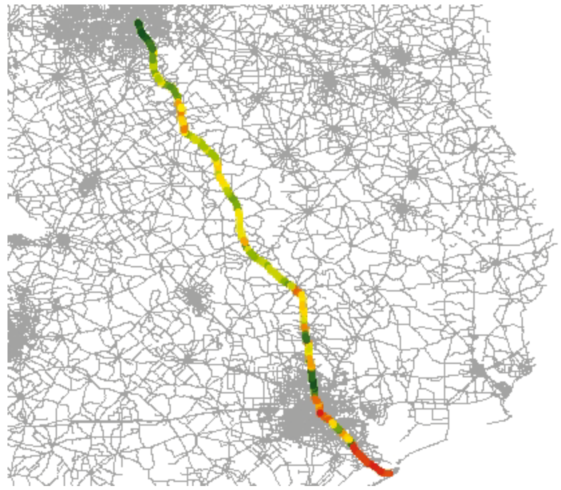


Figure 13: Scenario Two, Freight Value and DPMFocus, I-45 Corridor.

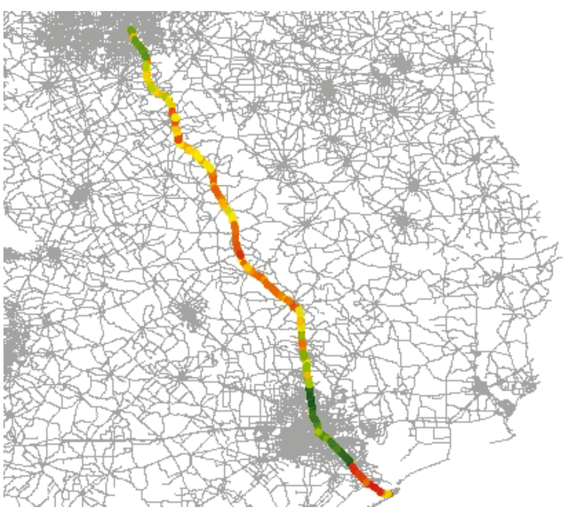


Figure 14: Scenario Three, Economic Value andPavement, I-45 Corridor.

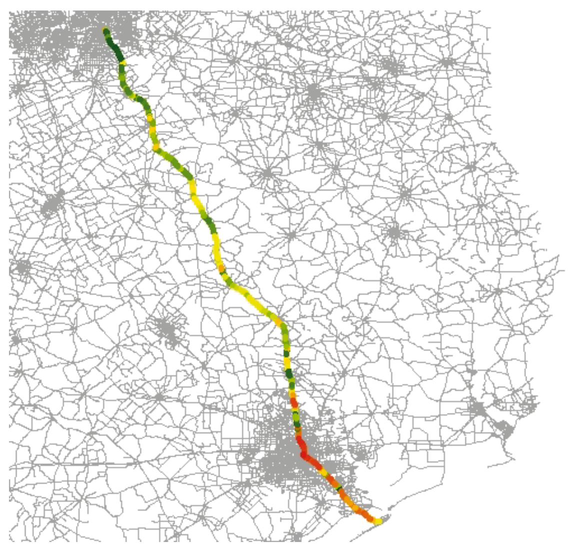


Figure 15: Scenario Four, DPM (Congestion) Focus,I-45 Corridor.

In Figure 16 through Figure 19, the four scenarios were applied to the Dallas micro-region. Figure 12 shows the base index, where all inputs are weighted equally. When Freight Value and DPM (Figure 13) are the focus, the areas of worst performance are fewer than the base index. When Economic Value and Pavement (Figure 14) are the focus, the index changes and shows a differentpicture of lower-performing segments in the corridor. When DPM is prioritized for congestion (Figure 15), the lower performing segments change.

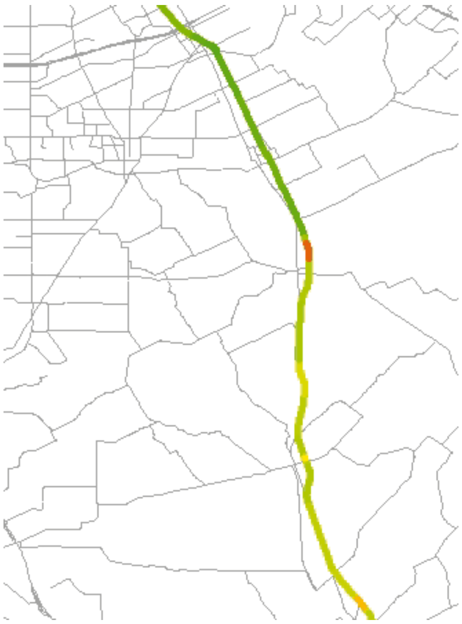


Figure 16: Scenario One, based index *representationfor Dallas.*

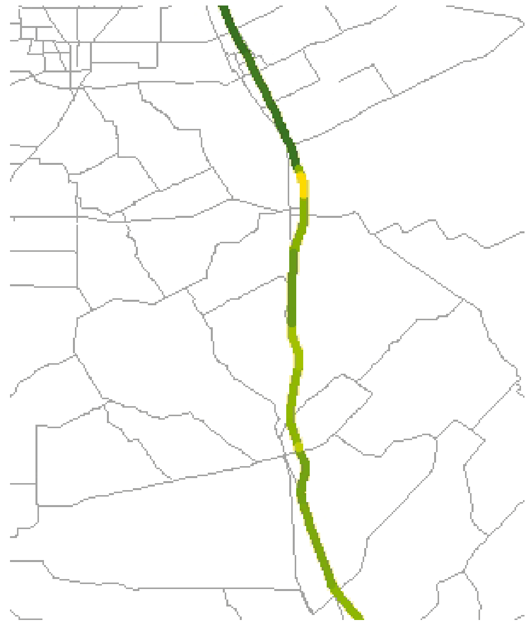


Figure 17: Scenario Two, Freight Value and Delayper Mile Focus, Dallas.

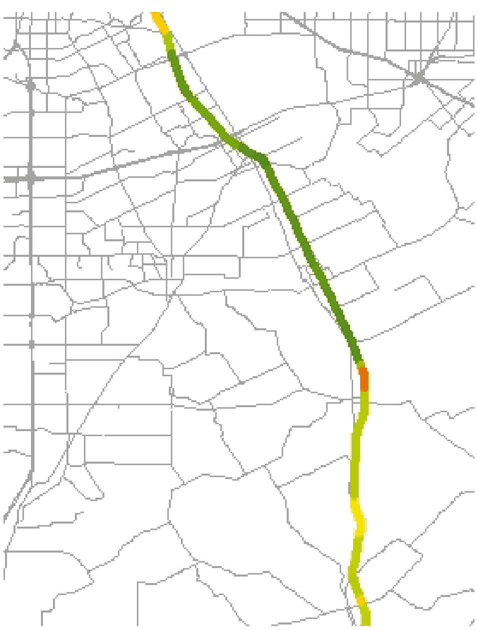


Figure 18: Scenario Three, Economic Value and Pavement Focus, Dallas.

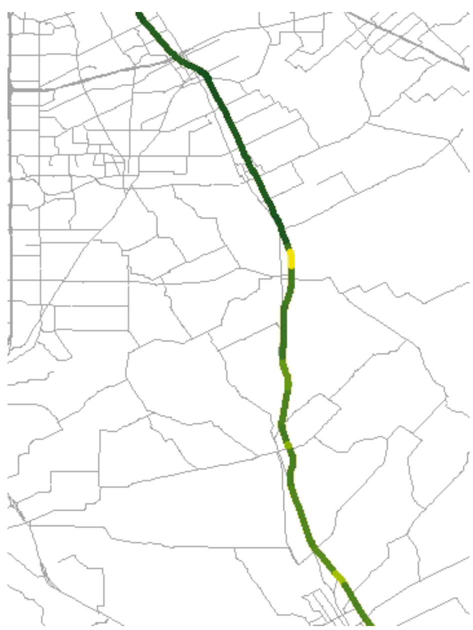


Figure 19: Scenario Four, DPM/Congestion Focus,Dallas.

Figure 20 through Figure 23 show the same scenarios for the Houston corridor subarea. When all four data layers are weighted the same, the center of the Houston region corridor appears worse(Figure 16), but when Scenario Two (Figure 21) is used, a different performance picture emerges with more of the segments showing lower performance. Scenario Three (Figure 22) presents a higher-performing picture for the region, while Scenario Four's reliance on congestion shows a corridor that is almost entirely low-performing (Figure 23).

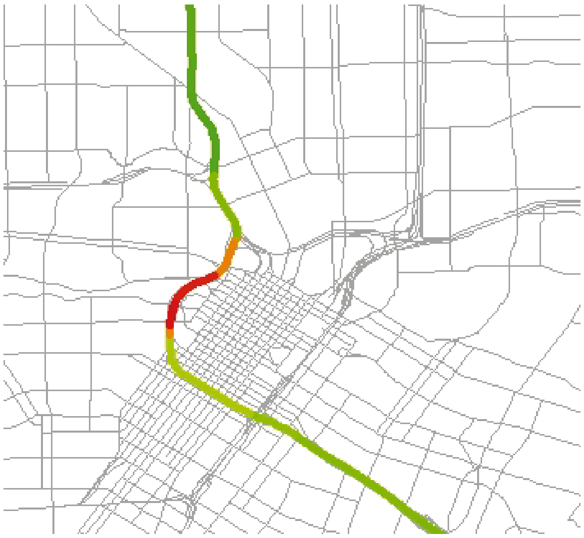


Figure 20: Scenario One, Base Index, Houston. Figure 21: Scenario Two, Freight Value and DPM/Congestion Focus, Houston.

Figure 22: Scenario Three, Economic Value andPavement Focus, Houston.

Figure 23: Scenario Four, DPM (Congestion) Focus,Houston.

Given the variability in results when different weighting is used, it is important to weight the categories based on the goals of corridor management efforts. If the goal is to improve congestion, DPM should be prioritized. If the effort seeks to manage assets, a different picture will emerge. If itis more holistic, a base index where weights are the same will help to evaluate performance altogether. Even if the goals are specific, it is important to adjust the weights and generate different visualizations for awareness of the interrelatedness of different data layers. This will help in discussions about corridor management efforts and the ways they can drive impacts in different ways, and how particular projects, programs, and policies could be incentivized or disincentivized accordingly.

5.3.9 Key Takeaways

TOSTADA is a tool that allows corridor management entities to understand the full need for, and effects of, transportation investment either in capital projects or operational/Transportation System Management and Operations (TSMO) treatments. Too often, these discussions are focusedon engineering evaluations when important economic and quality-of-life concerns may be addressed by the projects, programs, and policies being considered. TOSTADA's integrated maps provide a comprehensive and consistent set of information that can improve project comparison and selection, public engagement, and awareness of the relationship between mobility, safety, freight, economic value, and asset conditions.

TOSTADA is an appropriate means of analysis for decision-making if an agency performing corridor management requires an objective, data- and performance-based way to compare resource allocation choices and the effect of investments and financial constraints. The layered performance analysis offered by TOSTADA provides a thorough assessment of diverse and sometimes competing needs. A roadway safety project, for example, may also provide improvements in congestion, bridgeand pavement conditions, and the value of freight moved.

TOSTADA can also be used for project scoping and risk management, as well as to better communicate project benefits to the public and elected officials in planning and grant application documents. TOSTADA also allows analysts the opportunity to view performance trends over time; and, in the future, TOSTADA may have utility for agencies performing corridor management by examining the resiliency of the transportation system under automated vehicle (AV) and connected vehicle (CV) scenarios.

5.3.10 Relationship to Other Tools and 7-Ds

TOSTADA is intended to be used as part of a toolkit. While it can provide robust information about the roadways in the corridor, TOSTADA can be used as one part of a set of complementary resources that can provide additional decision-making context.

One way these tools can complement each other is by evaluating zones from a 7-D-type assessment and, through TOSTADA, identifying the segments within those zones that are the worst-performing locations. This approach provides a more revealing picture of the transportation problems and solutions for the regional network. As an example, an area with a low distance to transit score that includes roadways within the corridor showing high congestion might suggest that a transit strategycould help.

Alternatively, outputs of other tools, especially if they can be attributed to a roadway segment or attached to highway segmentation, could be used in TOSTADA. More research is needed to explore how to layer and consider the results of various tools and resources that can provide area or corridor-specific information.

5.4 Impact on Development Readiness: Master Architecture & Managing the Corridor System Blueprint

5.4.1 Background and Introduction

Method/Tool	Corridor Management Issue Addressed:
Master Architecture/ Corridor Blueprint	**Problem:** Most road networks are built with a limited planning horizon that fails to consider the needs of the corridor's supporting roadway system beyond the limited planning horizon.
	Summary of Solution: Apply an ITE-suggested road sufficiency framework to assess sufficiency of intersections counts and roadway mileage of the present and planned roadway network.

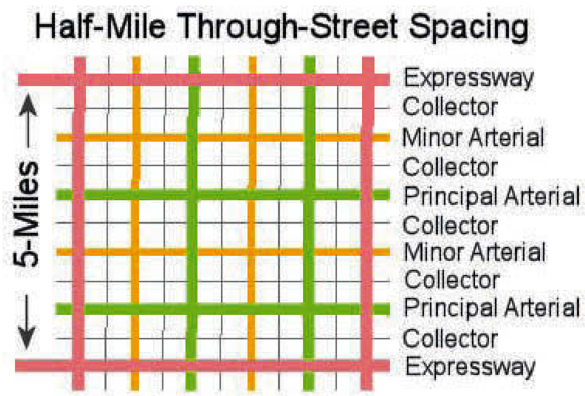
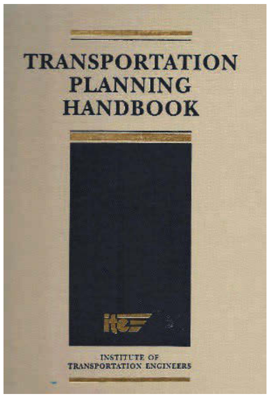


Figure 24: Spacing suggestion identified inNCHRP 917, Right-Sizing

One best practice strategy for positively influencing the long-term management of critical corridors is to first know the status of the corridorwith regard to its resilience in terms of alternative routes and a good circulatory support network – aiming to increase network density, or otherwise compensate if determined to be insufficient.

At its heart, this is a spatially based "development readiness" evaluation rather than a demand-based, fiscally constrained project justification effort. Regardless of when a corridor may have funding for a support network, this method will increase the odds that affected communities will preserve right-of-way for that support network. For communities that are fully developed, it will motivate them to increase their support network as much as possible, as well as give them reasonsto support efforts to compensate for an inadequate support network.

Ideal Network Spacing: So, what is an "ideal" corridor support network? A candidate structure for benchmark comparison was recently published in the new NCHRP Report 917 Right-sizing guidebook. The basic pattern of that structure is shown in **Figure 23**. The pattern is based on recommendations by the Institute of Transportation Engineers, **Figure 24**, that suburban areas, when fully developed, would do well to have a collector street every half-mile, a minor arterial every two-miles, a major arterial every two miles, and a freeway or expressway every 5-miles.This structure creates alternative paths for segments facing reconstruction, incidents, or recurring congestion. If an urbanizing area also ensures that at least some of this support structure also preserves right-of-way for transit and enhanced



active modes, then suburban-level densities can more easily keep growing to urban-level densities, avoiding Greyfield collapse in both value and activity density. Every region is different – some have high trips per square mile, others will always be low due to wetlands, mountains, and existing development that may be nearly impossible to intensify. Is 1-mile spacing between arterials truly necessary everywhere? Is an expressway every 5-miles excessive? Or would 7-10 miles between expressways work well? The ITE guidance is mainly a “rule of thumb” suggestion. This document describes how to utilize this spacing guidance to evaluate whether a corridor has a sufficient support network so that stakeholders can evaluate their options if the support network is found to be inadequate.

Figure 25: ITE publication with idealized grid spacingsuggestions.

5.4.2 Data and Overview of Procedure

Data Inputs:

Geodata of an existing street network; either a travel demand model network or a road centerline file.

A “Network Tile” Benchmark:

This procedure requires a “Network Tile” as its basic unit of measurement. The 5x5 tile described by ITE is a good starting point. A close study of this benchmark pattern reveals that a 5x5-mile grid, if divided every half-mile by a through street, will have 10 EW alignments as well as 10 NS alignments.

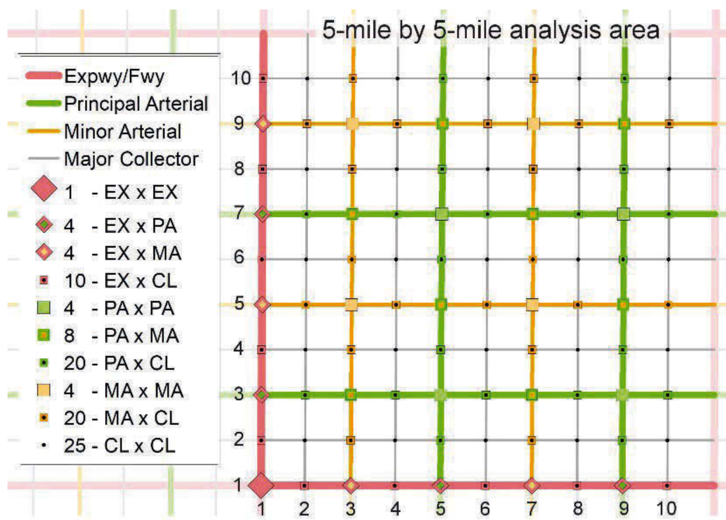


Figure 26: Total intersections by type within a 5x5-mileidealized network.

Considering only East-West, there will beexactly one expressway or freeway, two principal arterials, two minor arterials, five collectors, and the same for north-south streets. The result is a “tile” with 20 streets and 100 intersections in a 25 square mile area or four intersectionsper square mile.

Figure 25 diagrams the total number of crossings by facility type in a 5x5 area. Notice that while a 5x5 tile is bounded by four expressways, only two of the four can be assigned to this tile, while theothers belong to different tiles.

Figure 26, is the same as **Figure 25** but shows the totalcrossings within a 25 square mile area in tabular form.Dividing the top table by 25 results in a "crossings per square mile" measure of network density for the benchmark condition. Notice the red numbers, which show that out of the 100 intersections in a 5x5 square, 25are collector/collector crossings. On a per square mile basis, there are a total of four crossings, one of which willbe collector/collector, and the other three are various combinations of crossings. 75% of all crossings involve a collector in the 5x5 pattern.

What do you have in a 5x5 area?

		NS EX	NS PA	NS MA	NS CL	Total
EW	EX	1	2	2	5	10
EW	PA	2	4	4	10	20
EW	MA	2	4	4	10	20
EW	CL	5	10	10	25	50
Total		10	20	20	50	100

Crossings per square mile (divide by 25)

		NS EX	NS PA	NS MA	NS CL	Total
EW	EX	0.04	0.08	0.08	0.2	0.4
EW	PA	0.08	0.16	0.16	0.4	0.8
EW	MA	0.08	0.16	0.16	0.4	0.8
EW	CL	0.2	0.4	0.4	1	2
Total		0.4	0.8	0.8	2	4

Figure 27 Crossings by type: 25-SqMi,and 1-SqMi

While corridor resiliency is more concerned with alternative paths than the number of intersections, intersection density by type is an indirect measure of thenumber of alternative paths: i.e., if you have sparse facilities of a certain type, then you will also have a low intersection density for that type.

<u>**Defining the Attributes of a Measurement Tile**</u>: Neither ITE nor Report 917 expanded on the detailsof what is meant by "collectors, arterials, and expressways." To create a measurement index, a typical number of lanes and a daily capacity threshold should be defined for these functional types.

Then the tile can be used for measures like "lane miles per square mile" and "maximum VMT per square mile." Because roadway attributes vary so much, it is difficult to locate much more than qualitative descriptions of functional classes in most publications. There seems to be no standard for typical lanes, typical length, access control standards, or peak hour or daily capacity estimatesby functional class.

However, the case research finds that the Wasatch Front Regional Council, MPO for the Salt Lake area, has defined these attributes by functional class using the Highway Capacity Manual, and it isexpected the same method should be generally applicable across most regions[1]. For use in their travel demand model, they first estimate capacity per hour per lane for various functional classes.Once WFRC has created peak-hour Level-of-Service E capacities by facility type and number of lanes, they convert that to a daily capacity by assuming that on average about 9% of daily volumeoccurs in the PM peak hour. The result is shown in **Figure 27** as the maximum Average Daily Traffic (ADT) that can be supported by a facility with that number of through-lanes in each direction, assuming LOS E for the peak-hour capacity.

Cross-Section Ln	2-3	4-5	6-7	8	10	12	14
Lanes per dir	1	2	3	4	5	6	7
Freeway	-	83,000	118,000	150,000	178,000	203,000	227,000
Expressway	-	41,000	59,000	77,000	-	-	-
Principal Arterial	-	35,000	51,000	66,000	-	-	-
Minor Arterial	17,000	33,000	47,000	61,000	-	-	-
Major Collector	14,000	27,000	-	-	-	-	-
Minor Collector	8,000	-	-	-	-	-	-
Local	3,000	-	-	-	-	-	-

Note 1: A freeway with 2-lanes each direction carries 83,000 per day as the sum of both directions. A two-way principal with 2-lanes each direction (likely a 5-lane cross-section) carries 35,000 as the sum of both directions. A one-way principal arterial with 2-lanes will be (35,000 / 2) * 1.20 = 21,000, or 42,000 as the sum of two streets in a one-way couplet. This is because one-ways have about 20% more capacity per lane since they do not need left-turn signal phases.
Note 2: This is two-way ADT. To apply to each half of a facility, divide values by two.

Figure 28 Typical AADT for the 5x5 Benchmark Tile. Red is used in latercalculations.

To establish the maximum VMT within the benchmark 5x5-mile tile, is an "Expressway" at-grade or grade separated? The benchmark assumes 3 of 4 expressways in urban areas are 8-lane freeways (4 lanes each direction), and the other one is a 6-lane at-grade facility that while signalized, is potentially possible to grade separately. Thus, the capacity of this "average expressway" is 3x150,000 ADT, plus 1x59,000, divided by four = about 127,000 ADT on theaverage expressway. The benchmark also assumes 2.5 lanes per direction on a typical Principal Arterial, which really means half of them have 3-lanes per direction while the other half have just 2-lanes, so thecapacity of a benchmark principal arterial is 43,000, which is the averageof 35,000 and 51,000.

Figure 28 shows the assumptions for roadways within the 5x5-mile benchmark,along with the typical ADT capacity (the daily volume where the peak hour is LOS E). While all roads in the benchmark tile run for 5-miles, in a typical real-world application these facility types should have a length at least as shownin the table to be considered valid for comparative analysis.

Figure 29 Attributes of corridors within an idealized 5x5-milebenchmark network

	Length	LN/Dir	Access Control	ADT Max
Expway / Fwy*	10+ miles	3.75	Very Significant	127,000
Principal Arterial**	5+ miles	2.5	Significant	43,000
Minor Arterial	3+ miles	2	Some	33,000
Major Collector	1+ miles	1	Minimal	14,000

* Benchmark assumes 3 of 4 are 4-ln fwy. The other is 3-ln at-grade (each dir)

** Benchmark assumes half have 3-ln each dir, and half have 2-ln each dir

<u>Benchmarking Network VMT Capability:</u> **Figure 29** shows the number of facility miles by type within a 5x5 tile, as well as the ADT that can be managed at LOS E on that facility type. Multiply the total facility miles by the ADT that each facility can handle, and you get a "theoretical maximum VMT" that can be managed within a 5x5 area by facility type. This assumes that all facilities are 100% full at the PM peak hour. It is unlikely that all facilities will be at 100% in peak hours, but it will serve well as a benchmark when compared to the theoretical maximum of real systems, to demonstrate their adequacy or inadequacy for managing buildout traffic levels.

Notice that while Expressways and Freeways are 10% of the total facility-miles in the benchmark,they can carry up to 36% of the 5x5 VMT.

Collectors are 50% of the system but carry just20% of the system load. This should not denigrate the value of collectors, however, as they are very affordable relative to other facilities, and fill critical spacing gaps.

Figure 30 is the same but replaces the two expressways in a 5x5 area with one principal arterial and one minor arterial. The purpose ofthis replacement is to create a benchmark for urban at-grade corridor studies that do not involve either a freeway or expressway within the study area.

VMT Capability per 5x5-mile Benchmark Tile (includes Expwy/Fwy)

Functional Class	Lanes / Dir	Facility-Miles	Lane-Miles (2-dir)*	Pct of F.Miles	ADT Max	VMT per 25 SqMi	Pct of Total
Expwy / Fwy	3.75	10	75	10%	127,000	1,270,000	36%
Principal Arterial	2.5	20	100	20%	43,000	860,000	25%
Minor Arterial	2.0	20	80	20%	33,000	660,000	19%
Collector	1.0	50	100	50%	14,000	700,000	20%
Total		100	355	100%		3,490,000	100%

VMT Capability per Square Mile (divide 25)

Functional Class	Lanes / Dir	Facility-Miles/SqMi	Lane-Miles per SqMi*	Pct of Miles	ADT Max	VMT per SqMi	Pct of Total
Expwy / Fwy	3.75	0.4	3	10%	127,000	51,000	37%
Principal Arterial	2.5	0.8	4	20%	43,000	34,000	24%
Minor Arterial	2.0	0.8	3.2	20%	33,000	26,000	19%
Collector	1.0	2	4	50%	14,000	28,000	20%
Total		4	14.2	100%		139,000	100%

* Note: Lane-Miles = Facility-Miles * Lanes / Dir * 2-directions

Figure 30 VMT capability per 5x5 "block" and per square mile

[1] Source file: WFRC, SPD-CAP, Grid Analysis.xlsx

5.4.3 Key Benchmark Summary

Here is a summary of key observations fromthe benchmark condition:

- Four total intersections per square mile
- 3 of 4 intersections involve a collector
- About 14 lane-miles per square mile, summed across all facility types in all directions (excludes TWLTL, Aux lanes, etc.).
- 139,000 VMT per square mile is the benchmark theoretical maximum for study areas that involve expressways or freeways
- 104,000 VMT per square mile is the benchmark theoretical maximum for study areas that do notinvolve expressways or freeways

VMT Capability per 5x5-mile Tile (Expwy/Fwy replaced by arterials)

Functional Class	Lanes / Dir	Facility-Miles	Lane-Miles (2-dir)*	Pct of Miles	ADT Max	VMT per 25 SqMi	Pct of Total
Principal Arterial	2.5	25	125	25%	43,000	1,075,000	41%
Minor Arterial	2.0	25	100	25%	33,000	825,000	32%
Collector	1.0	50	100	50%	14,000	700,000	27%
Total		100	325	100%		2,600,000	100%

VMT Capability per Square Mile (divide 25)

Functional Class	Lanes / Dir	Facility-Miles/SqMi	Lane-Miles per SqMi*	Pct of Miles	ADT Max	VMT per SqMi	Pct of Total
Principal Arterial	2.5	1	5	25%	43,000	43,000	41%
Minor Arterial	2.0	1	4	25%	33,000	33,000	32%
Collector	1.0	2	4	50%	14,000	28,000	27%
Total		4	13	100%		104,000	100%

* Note: Lane-Miles = Facility-Miles * Lanes / Dir * 2-directions

Figure 31 Same as before but excludes Expressways for use in corridor analysis where expressways are not present.

At the collector level, it can be hard to find a network which identifies collectors in a similar way as the benchmark: some source GIS files show collectors that are too short ortoo impractical to really be counted as a significant collector. Other GIS files, often from travel demand models, exclude collectors that probably are significant enough to be counted. Alternate non-collector benchmarks for more reliable arterial networks can be used instead.

With square mile benchmark metrics defined, it is possibleto take any shape of corridor study area and compare its intersections per square mile, lane-miles per square mile, and VMT capacity per square mile to that of the benchmark. This will tell us how well the corridor's overallnetwork is able to support buildout development at suburban to urban densities.

5.4.4 Method for Preparing Starting Data

The applicability of this technique is primarily within fully developed urban areas, or areas likely to see significant development over the next 50-years that need guidance onpreserving space for an adequate network. Technical aspects of this procedure are primarily accomplished in GIS. Within a study area such as an MPO boundary or an urbanized or urbanizing county, obtain or create the following GIS files:

1. Create GIS file of Existing + Planned Network by Functional Class: Starting from an MPO travel model network or a county centerline network, classify each roadway as a major collector, minorarterial, major arterial, expressway, parkway, freeway. Anything below these can be ignored. Major collectors may also potentially be ignored if it is hard to know if your dataset is missing many major collectors, or if it has too many streets labeled as major collectors that in practice will never really offer much mobility utility.
    a. Note: If intersections per square mile are of interest, take care that freeways and divided highways show up only as a single line (as that is how expressways in the benchmark aredepicted).

   b. <u>Lanes</u>: Each facility should show the number of travel lanes on the facility, excluding TWLTLs or any auxiliary lanes. A two-way street with 2-lanes in each direction should show “4” as the number of lanes. A one-way street would show “2” as the number of lanes. A freeway with 5-GP lanes and 1-HOV lane per direction would show “12” as the number oflanes.
   c. <u>Illustrative Projects</u>: In addition to fiscally constrained horizon-year corridors that do not yet exist, “Illustrative corridors” that have had significant discussion, even if not yet being actively preserved, can also be identified on the “existing + planned” network. Such illustrative projects may benefit from a unique color to review their buildout value, but also note that no one has yet committed to preserving these corridors.

2. <u>Assign an AADT capacity to each facility</u>: Using values from Table 2 (or another source), determine how many vehicles per day the facility can serve. For one-way streets, select the closest two-way street, divide by 2, then multiply by 1.2, as a one-way’s capacity per lane is about 20% higher on average since one-way streets do not require left-turn phases at signals.
   a. For freeways, auxiliary lanes do not count as lanes but add in the capacity of anycollector/distributor roads.
   b. For major collectors, assign either 14,000 from **Figure 27**, or a maximum value thecommunity could tolerate, (such as 5,000).
   c. **Figure 27** can be regenerated with local data if you have a good source for these values.

3. <u>Overlay a “Fishnet Grid” tile structure onto the corridor</u>:
   a. Suppose the corridor of analysis is a freeway that runs slightly tilted off a north-southaxis. Draw a straight “axis line” the generally overlays the freeway and is also slightly tilted.
   b. Create a “fishnet grid” for the study area by copying the axis line to the left and right inhalf-mile increments. Create east-west streets in the same way.
   c. Create a “Tile ID” field. Starting at the axis, number 1-10 if a 5x5, or 1-14 if a 7x7, etc.
   d. Define the functional class of each ID as per **Figure 31**.

Note: At this point, you will have two roadway sets for the corridor: 1) The existing + planned roadways, 2) The Fishnet overlay hypothetical roadways (or benchmark measurement roadways).In GIS, you may want to set up two side-by-side views for each.

Fishnet pattern for 5x5-mile tile, where buildout is likely to be heavy suburban to urban

Miles from Axis	-	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
Roadway ID	1	2	3	4	5	6	7	8	9	10	Rpt	2	3
Functional Class	E	C	M	C	P	C	M	C	P	C	E	C	...

Fishnet pattern for 7x7-mile tile, where buildout includes significant open space or low density

Miles from Axis	-	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0
Roadway ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Rpt	2	3
Functional Class	E	C	P	C	C	M	C	C	P	C	C	M	C	C	E	C	...

Figure 32 5x5-mile Fishnet tile pattern and 7x7 tile pattern

Note: If the corridor of interest is a lower functional class, yet an expressway is part of the study area, you may still want to select the expressway as the axis rather than your study corridor. This part is about creating a compelling visual that is easy to understand, so "artwork" experimentationis appropriate.

4. <u>Additional Helpful Data</u>: It will be helpful to utilize GIS information to depict any large areas of undevelopable land, such as regional, state, national parks, wetlands, designated perpetual openspace, lakes, mountains – anything that could help explain why portions of the corridor would never need the full support network implied by the fishnet grid. Small parks, small cemeteries, schools with large fields – all of these are part of the general urban fabric and too small to influence the selection of a "Fishnet size." However, all these layers will later be helpful if aimingto add new corridors for preservation on master transportation plans.
5. <u>GIS, Planned Land-uses</u>: If this layer is readily available, it will also prove useful. There are nuances in how the architecture framework can be applied depending on how the area is expected to evolve.

5.4.5 Computing Corridor Measurements

The process to compute statistics for both the Fishnet benchmark network as well as the actual existing + planned network. Can now be accomplished. The process of computation will be shown in Section 5.4.7 through an example case for two portions of I-85 through Atlanta. But first, Figure 32 will describe outputs of the process and where this method can be most helpful.

5.4.6 Describe outputs

Outputs for this process consist of Facility-miles per square mile, lane-miles per square mile, intersections per square mile, and VMT capability per square mile for both 'Fishnet' benchmark grids as well as actual grids.

This procedure is compelling at the fringes of a growing area, where there is still a great opportunityto influence corridor preservation. If a practitioner can reach these areas early and demonstrate toa community that their plans are woefully insufficient for buildout, it will be much easier for that community to simply add new alignments to their existing plans. It can also be used to identify locations in existing road networks where connectivity is most lacking and where making an effort to connect the existing street network can do the most good.

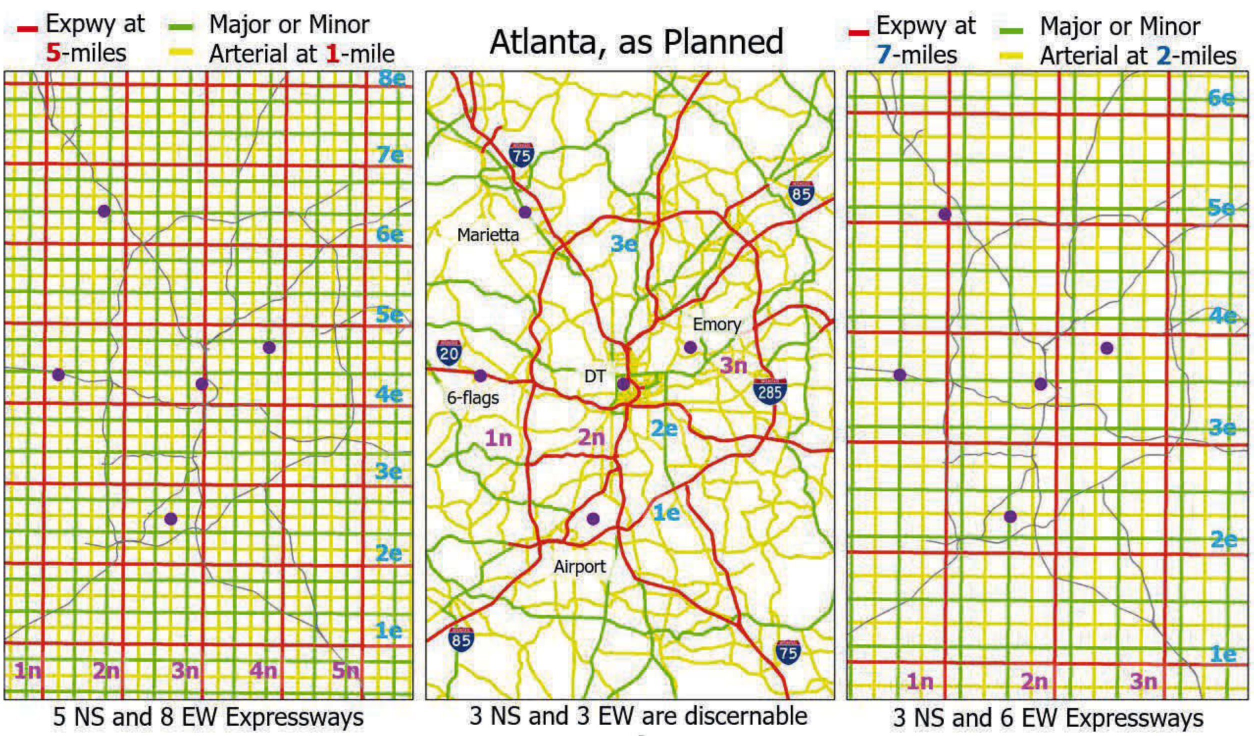


Figure 33: Atlanta vs two "fishnet grid" analysis frameworks.

5.4.7 Application Cases in Georgia and Utah

Application in Atlanta, Georgia

Figure 33: Atlanta vs two "fishnet grid" analysis frameworks is a broad overview of Atlanta. On theleft are multiple 5x5 tiles and 1-mile arterial spacing. The right side is 7x7 tiles with 2-mile arterial spacing. The 5x5 tiles are designed for resiliency in areas with "above average" suburban/urban densities. 7x7 tiles may work well with "below average" densities. You can clearly see that even forbelow-average densities, Atlanta lacks both regional expressways and a support structure of arterials. The result is too much traffic on two few roadways. This visual is an effective "Big Picture" of the problems trans-national corridors face as they traverse many major urban areas.

Also, within this view are many smaller regional freeway corridors and even smaller at-grade arterial corridors that can be zoomed in on to study in more detail using this method. While the statistical analysis described earlier *can* be conducted for the entire region, the current example will not go to that scale as it is not necessary for corridor analysis. Instead, this corridor application will focus on sub-corridors centered around I-85 to demonstrate this method. This image is provided only for context. However, a corridor study may also want to consider developing a county-sized overlay to provide stakeholders with a big-picture visual context, then zoom in to the study area for more detailed visuals and for creating corridor-level analysis.

5.4.8 The Math of Atlanta's I-85 Corridor

Section 1 included an overview of a process to determinefacility-miles per square mile, lane-miles per square mile,intersections per square mile, and VMT capability per square mile. The method was applied to a 5x5-mile benchmark measurement tile and will now be applied to the I-85 corridor in Atlanta to compare results against thebenchmark measurements. The GIS linework for this analysis comes from the Atlanta Regional Council's travel demand model, which has link segments that had to be processed to be comparable to the benchmark tile. This section describes the process of utilizing this ARC model network.

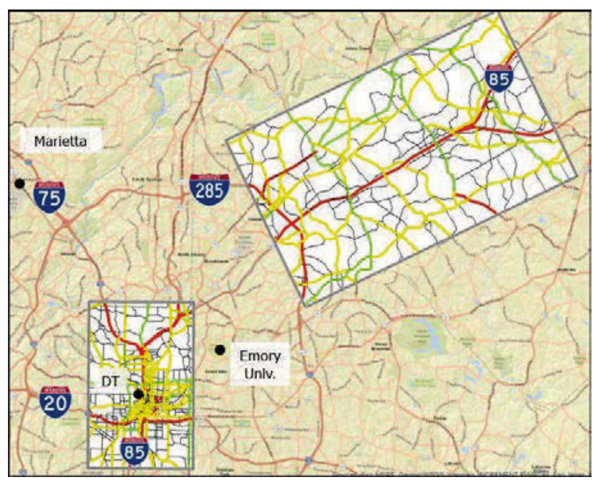


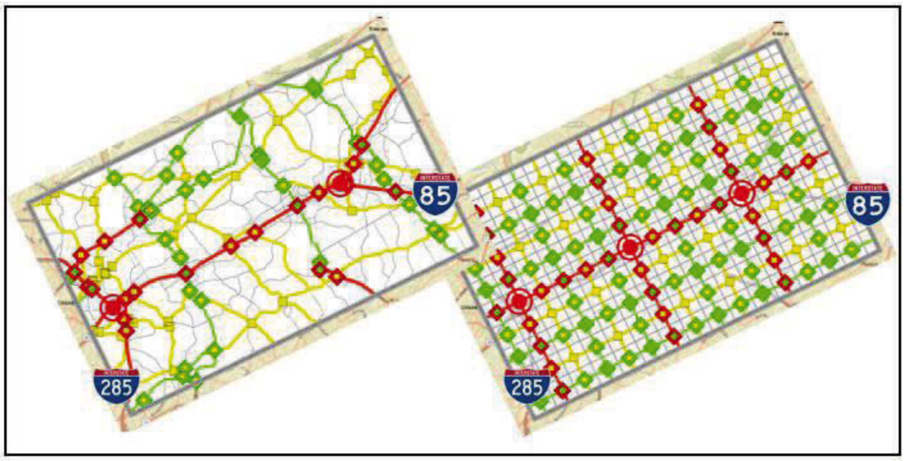
Figure 34: Two study areas of this example. Downtown vs Exurban

5.4.9 Overview Map

Within Atlanta, this analysis zooms in on two segments of I-85. The downtown area, and another segment northeast of downtown. **Figure 34** shows the twostudy areas.

5.4.10 Intersections per Square Mile

In GIS, you can create intersections at points where lines cross, then label each intersection with the functional types involved – Principal Arterial X Collector, Expressway X Minor, collector. **Figure 35** shows the intersection density for the northeast study area in comparison to the benchmark network. The top half of the table shows the total number of intersections in both the benchmark and in the actual. The bottom half is the top divided bythe total square miles. The red percentages are where the actual intersections are considerably less than the benchmark. Yellow would be 75%-99% of the benchmark, and green if 100% or higher.



Intersections	SqMi	147.0	
	I-85 North		
	Bench	Actual	Pct
Exp X Exp	6	2	33%
Exp X Art	20	10	50%
Art X Art	60	35	58%
Collectors	160	80	50%
Total	246	127	52%
Intersections per Sq Mi.	I-85 North		
	Bench	Actual	Pct
Exp X Exp	0.0	0.0	33%
Exp X Art	0.1	0.1	50%
Art X Art	0.4	0.2	58%
Collectors	1.1	0.5	50%
Total	1.7	0.9	52%

Figure 35 Intersections per square mile, actual vs 5x5-mile fishnet overlay

Care should be taken to represent freeways as single-line schematics, ratherthan multi-alignment features with ramps, managed lanes, separate sides, and anything else that isn't comparable to the benchmark. This is so a cross- street will create just one intersection with the freeway rather

5.4.11 Facility Mile Visual Comparison

Just seeing the total number of corridor-supporting roadways helps reveal the extentto which there is over-dependence on the primary corridor.

In **Figure 36**, notice that in the northeast area, the fishnet overlay has far more roadways of every kind than the actual areahas.

Also notice in **Figure 37** that downtown appears largely the opposite, where the actual area with a high number of significantstreets, especially in the central core.

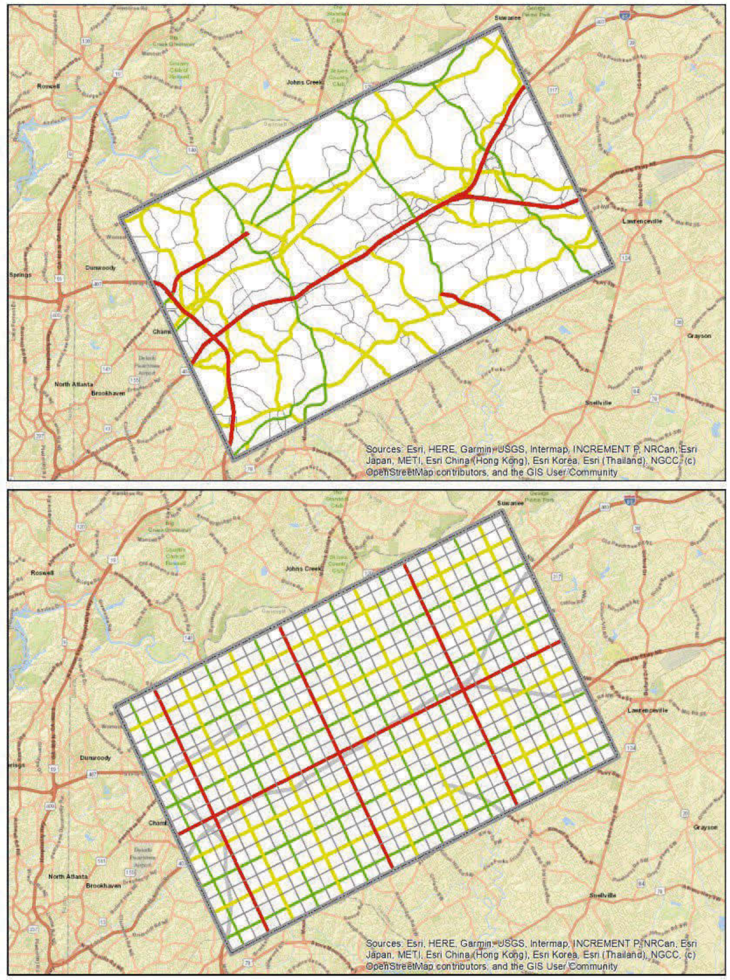
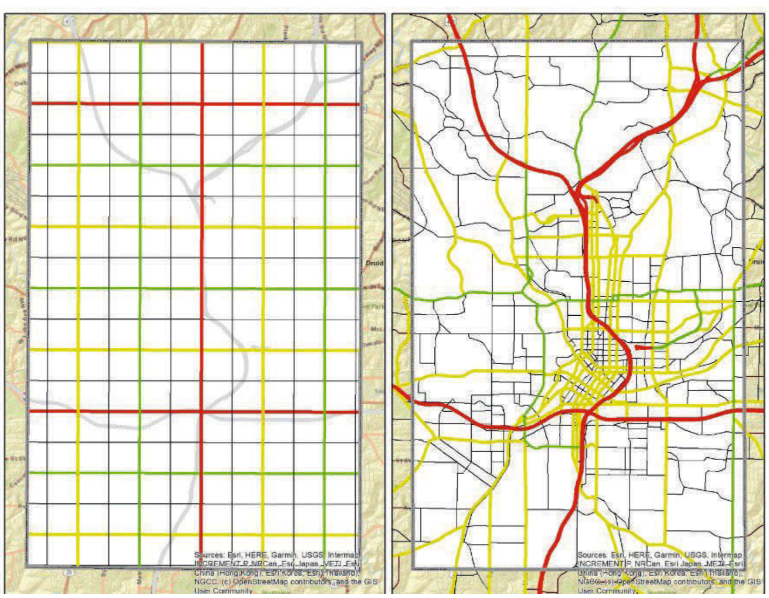


Figure 36 Network by functional class along I-85, northeast ofAtlanta.

Lane Miles	SqMi	46.0	
	Downtown		
	Bench	Actual	Pct
Expressway	116	235	202%
Principal	155	298	192%
Minor	167	90	54%
Collector	200	353	177%
Total	638	976	153%
Lane Miles per Sq Mi.	Downtown		
	Bench	Actual	Pct
Expressway	2.5	5.1	202%
Principal	3.4	6.5	192%
Minor	3.6	2.0	54%
Collector	4.3	7.7	177%
Total	13.9	21.2	153%



Facility Miles	SqMi	147.0	
	I-85 North		
	Bench	Actual	Pct
Expressway	44	35	80%
Principal	119	50	42%
Minor	119	122	102%
Collector	307	181	59%
Total	589	388	66%
Facility Miles per Sq Mi.	I-85 North		
	Bench	Actual	Pct
Expressway	0.3	0.2	80%
Principal	0.8	0.3	42%
Minor	0.8	0.8	102%
Collector	2.1	1.2	59%
Total	12.8	8.4	66%

5.4.12 Lane-Miles per Square Mile

When a fully developed area doesn't have many through streets, it often tries to "build its way out of congestion" by making the roads it does have far larger than they otherwise would have been.

In Figure 37, it would appear from this comparison of facility-miles to lane-miles that this is what Atlanta has done in the northeast. Notice that while expressway facility-miles are 80% of the benchmark, lane-miles is 143%. Several other categories are similar.

Facility Miles	SqMi	147.0	
	I-85 North		
	Bench	Actual	Pct
Expressway	44	35	80%
Principal	119	50	42%
Minor	119	122	102%
Collector	307	181	59%
Total	589	388	66%

Lane Miles	SqMi	147.0	
	I-85 North		
	Bench	Actual	Pct
Expressway	264	378	143%
Principal	595	417	70%
Minor	476	251	53%
Collector	614	478	78%
Total	1949	1525	78%

Facility Miles per Sq Mi.	I-85 North		
	Bench	Actual	Pct
Expressway	0.3	0.2	80%
Principal	0.8	0.3	42%
Minor	0.8	0.8	102%
Collector	2.1	1.2	59%
Total	12.8	8.4	66%

Lane Miles per Sq Mi.	I-85 North		
	Bench	Actual	Pct
Expressway	5.7	8.2	143%
Principal	12.9	9.1	70%
Minor	10.3	5.5	53%
Collector	13.3	10.4	78%
Total	42.4	33.2	78%

Figure 38 Benchmark & Build Facility Miles, Lane Miles, I-85 northeast

5.4.13 VMT Capability perSquare Mile

Recall that if you know the ADT capacity of any given roadway, and you also knowhow long that road is, then miles * ADT capability = VMTcapability, or the maximum VMT that roadways in the area could support.

In **Figure 38**, notice that forI-85 northeast, the expressway category has higher VMT capability than the benchmark, most likely because all other categories have less than the benchmark. In practice this probably means local residents are using the freeway for short trips, because they lack other options. The result is a super-sized freeway with less throughput per lane with each additional lane (due to lane utilization inefficiency, higher odds of incidents, etc.). Downtown has higher VMT capability than the benchmark, which makes sense for the highest densities in the region.

VMT Capability	SqMi	46.0	
	Downtown		
	Bench	Actual	Pct
Expressway	1,000,000	1,200,000	120%
Principal	500,000	350,000	70%
Minor	400,000	600,000	150%
Collector	30,000	60,000	200%
Total	1,930,000	2,210,000	115%

VMT Capability	SqMi	147.0	
	I-85 North		
	Bench	Actual	Pct
Expressway	1,000,000	1,200,000	120%
Principal	500,000	400,000	80%
Minor	400,000	300,000	75%
Collector	200,000	100,000	50%
Total	2,100,000	2,000,000	95%

VMT Capability per Sq Mi.	Downtown		
	Bench	Actual	Pct
Expressway	22,000	26,000	118%
Principal	11,000	8,000	73%
Minor	9,000	13,000	144%
Collector	700	1,300	186%
Total	42,000	48,000	114%

VMT Capability per Sq Mi.	I-85 North		
	Bench	Actual	Pct
Expressway	7,000	8,000	114%
Principal	3,000	3,000	100%
Minor	3,000	2,000	67%
Collector	1,400	700	50%
Total	14,000	14,000	100%

Figure 39 Benchmark & Build Facility Miles, Lane Miles, I-85 Downtown

5.4.14 Conclusion

This analysis of in Atlanta has presented an application of this analysis method for two different contexts, comparing intersection density, facility miles, lane miles, and maximum VMT. The analysishas shown that while both locations differ significantly from the idealized network, the downtown location differs less, suggesting that intensively developed locations, even if transit and pedestrian- oriented, require a street network capable of handling the traffic generated by that development. Effective corridor management requires taking long-term growth and development in the region into account so as to plan and preserve a road network sufficiently to ensure the provision of sufficient roadway facility miles to enable transformation to higher functional classes on an as- needed basis. Omitted roads cannot later be placed, and failure to preserve options in a timely manner results in the permanent impairment of the road network, increasing diversion, out of direction travel, and the concentration of traffic into a small number of locations then requiring special intersection treatments or grade separation to overcome.

5.4.15 Application in Utah County, Utah

Utah County, just south of Salt Lake, is experiencing rapid development. In an effort to protect the long-term health of I-15 and other lesser corridors in the area, they are looking not just at traditional horizon-year, fiscally constrained projects, but also at a broader corridor preservation program to help ensure there will be pathways available for the projects they will need both pre and post-horizon. This shows the steps they went through to start a "buildout conversation" so that their growing fringe communities can preserve corridors for post-horizon needs.

Step 1: Compare Existing Plans to "Hypothetical Ideal"

In **Figure 40**, the map on the right shows the county's 2040 planned network, which is a mix of bothexisting and planned roadways. The map on the left shows all developable areas as if they were fully developed and as if they had a "perfectly square" starting-point network, as described in NCHRP 917.

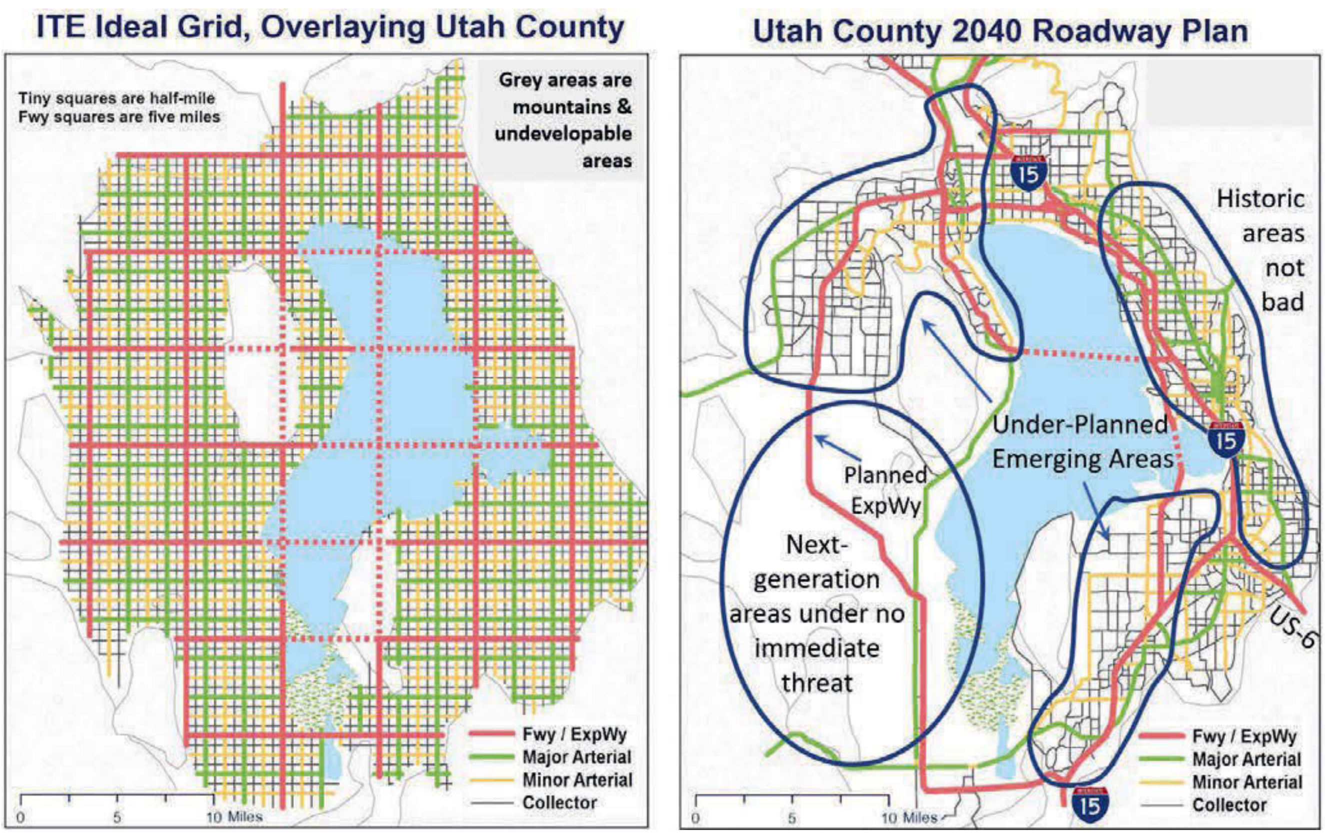


Figure 40 Perfectly Square, "Scottish Plaid" buildout pattern of streets vs. horizon year plan. Notice that theplan is too sparse for buildout and unless corridors needed beyond the horizon year are identified today as part of an eventual "Master Architecture," most likely they will not be preserved. The result will be excessivecongestion on the sparse network that was built.

Consider these observations:

- Historic Areas: Notice that the historic areas east of the lake generally have at least a collector street every half-mile. Historic areas have fewer arterials (orange and green) than the method suggests, but it is not a significant problem since the city hits a mountain at thatedge, and thus no additional development is possible to the east.

- Emerging Areas: The northwest and southeast both have large, fast-growing areas with relatively little development today. The streets shown in these areas are a mix of both existing and planned. But notice that emerging areas only have about half or less of the overall roads they would need if built out to the same densities as the historic areas. Because this is all that is currently planned, they risk seeing windy roads with lots of cul-de-sacs that will block their ability to create anything more than what they presently show. If that happens, the day will come where every road of significant length will become overwhelmed with congestion.
- Post-2040, Next Generation: The large area in the southwest is unlikely to even begin much development within the next 20-years, and thus can be "safely ignored" for most of that time. However, it is worth depicting its development potential nonetheless, largely so that today's emerging areas can plan for corridors that eventually must connect to it.

Step 2: Best Fit the Ideal to the Existing Reality

Even areas with very little existing development still have roadways at erratic angles, and there are lakes, mountains, large parks, or other features that will never be developed. While it doesn't makesense to have an extensive network through undevelopable areas, but it is reasonable to have a few crossings of large, sensitive areas. In **Figure 40**, the previous "Scottish Plaid" overlay suggests up to five east-west expressway crossings of the lake and three north-south. Prior to this effort, the county was debating whether topreserve opportunities for even just a single east-west lake crossing near the north end. The fully built-out scenario (right-map) suggests it might make sense to cross the lake in three spots, which would cut more than20 miles off of many trips.

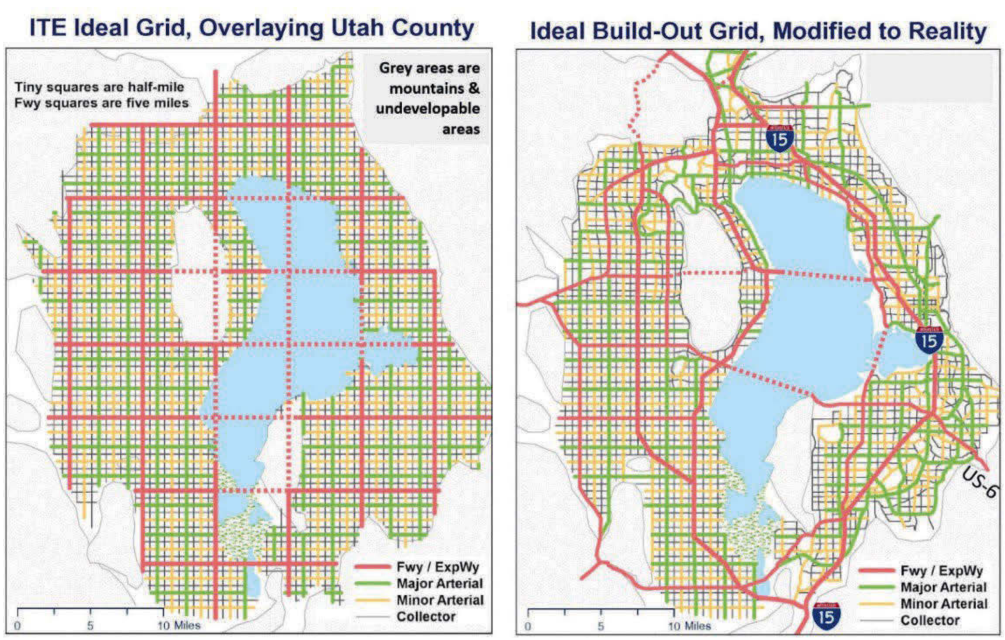


Figure 41 An attempt to "Best Fit" buildout needs with existing plans and constraints.

Note that in this case, creating the architecture suggests that several fiscally constrained projects should berescoped to slightly different locations or with a different eventual functional class.

The goal of Step 2 is to create somethingas close to ideal as possible, but also realistic in that it respects natural assets and avoids development obstacles. In the heavily built areas, the goal is to improve connectivity as much as possible, and also to consider functional class changes if connectivity is proving to be too sparse.

Figure 41 shows the process used to fit **Figure40** to existing terrain using an aerial photo (and other GIS constraintlayers). The process zooms into spaces wherethe network is not continuous but probably should be at buildout and selects an apparent path of least resistance to serve as a starting point of conversation with affected stakeholders.

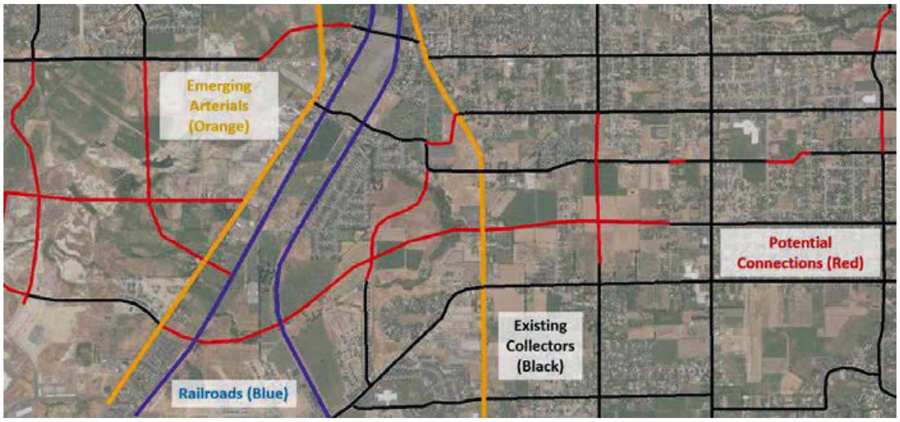


Figure 42: Process of Creating a "Best Fit" network. Red represents segments that are not shown on existing municipal plans, but many could be after somevetting.

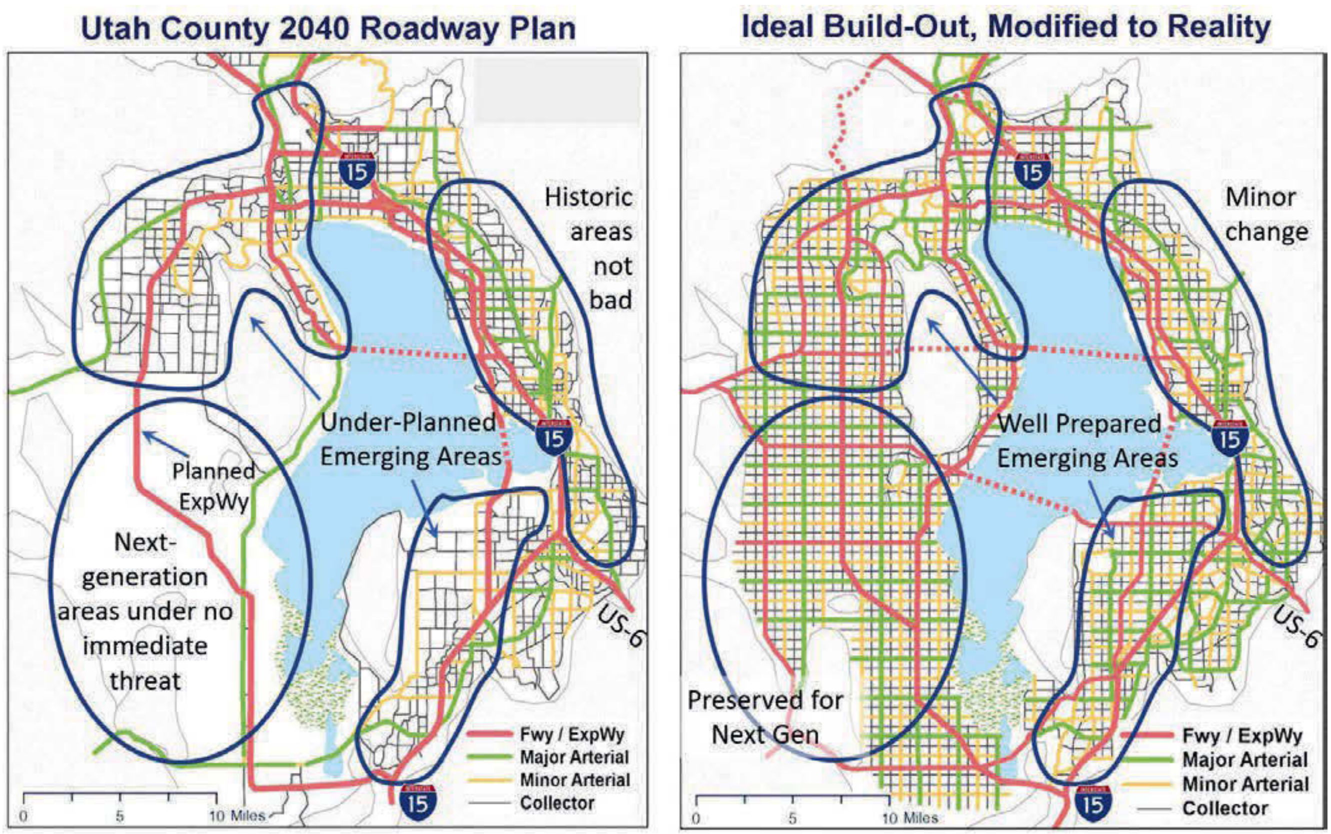


Figure 43 Original plan vs. Draft Master Architecture. The architecture is a "100-year" corridor preservation tool, helping to ensure that as the horizon year changes every now and then, that fiscally constrained horizonyear projects in the next cycle of the plan can be drawn from, or at least compatible with, the architecture.

Figure 43 compares the original 2040 plan against a **"First Draft Master Architecture."** A first-draft architecture will most likely be driven by a State DOT, MPO, RPO, or a county, but all lines should be considered general locations for preservation needs. However, to be of any practical use, these corridors must be exactly identified and preserved before too much development occurs. Thus, as soon as there is a risk that corridor options could be endangered, these fuzzy lines should be presented to those who live there to gauge their reaction and enlist their assistance in improving the location of proposed connections, and also to solicit their feedback on any potential functional class changes or alternative means of providing for the future.

Step 3: Identify Preservation Needs by Level of Urgency

Figure 44 shows that once the draft architecture is completed, the next step is to create a "Preservation Urgency" map. To do this, each new segment should be studied and classified as to the immediacy of the need for finalizing the location of needed corridors so they can be effectively preserved. In this example, black, red, and green show the preservation urgency of the largest corridors. Black means the county is almost out of time for securing any alignment for this criticalcorridor. Red means they have a little more time, but development is encroaching quickly. Green means that while it is a critical corridor, it will be many years before there is any risk that the best path might be consumed by development. Orange is for smaller corridors (arterials and collectors) that are being threatened by encroaching development but may not be on any municipal plan. If these small corridors are to ever exist, they need to be shown on local plans very soon.

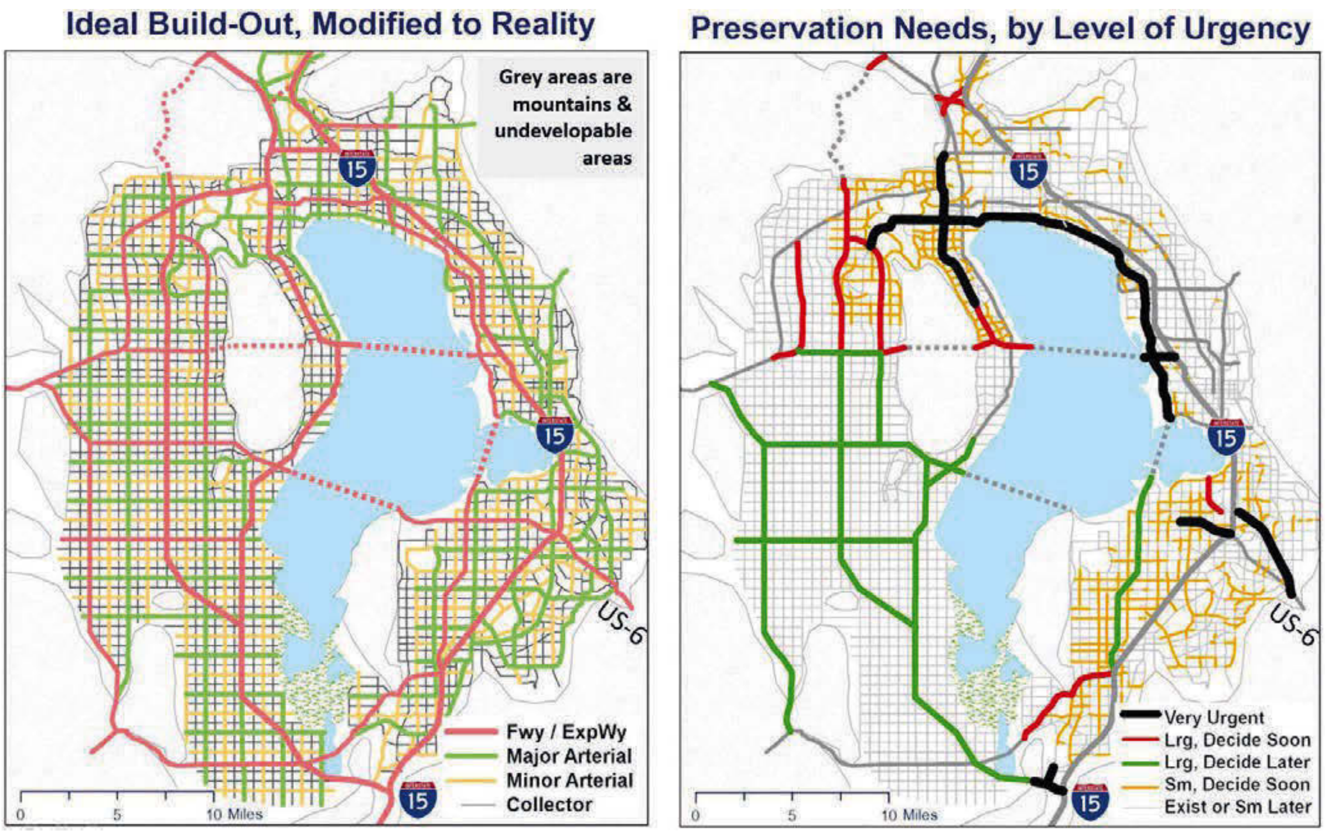


Figure 44: Preservation Urgency: Black, Red, and Orange corridors are experiencing rapid development thatwill soon result in dozens if not hundreds of residential and business impacts – a scale of impacts that could make it politically impossible to build needed corridors, resulting in excessive pressure on other primary corridors such as I-15.

Step 4: Identify Preservation Widths, Access Requirements, etc.

In order to preserve corridors, you need to identify not only reasonable locations for collectors, arterials, expressways, and transit you will need at buildout, but also establish an expectation of themultimodal cross-section and access control requirements. Figure 44 shows how a community might define their typical minor arterial at 125 ft – much wider than in the past to better accommodate premium streetscape and alternative modes. Utah County has not yet taken this step, but this would be a good next step for them.

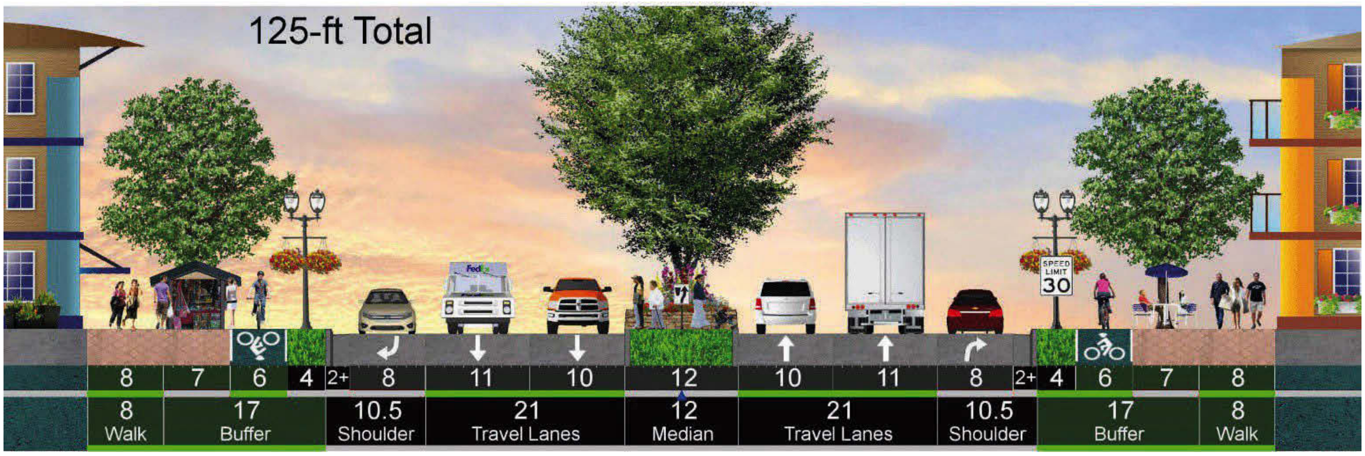


Figure 45: Candidate cross-section for Minor Arterial. Where past standards ranged from 80-106 ft, a community maydecide future corridor preservation standards should be higher at key locations to facilitate Complete Street design.

5.4.16 Takeaways

As cities expand, corridors that were once functioning very well can suddenly become overwhelmedwith traffic. As that happens, communities look to construct bypasses to help divert some of the load elsewhere. However, by the time a community realizes there is a need for a bypass, scattered development might have reached 10-50% of buildout levels. Even at just 10%, many pathways may be blocked. Corridors then get pushed into environmentally sensitive areas and may impose politically difficult impacts upon those directly in the path of least resistance, or upon those who are unhappy about being near a high-volume corridor that they didn't anticipate. Thus, a process for helping communities discover early that they are under-anticipating their buildout needs can increase the odds that they will preserve adequate space for the facility types they are lacking.

This procedure is very powerful at the fringes of a growing area, where there is still an excellent opportunity to influence corridor preservation. If a practitioner can reach these areas early and demonstrate to a community that their plans are woefully insufficient for buildout, it will be mucheasier for that community to simply add new alignments to their existing plans. Wait until it is painfully obvious that a greater support structure would be helpful, and by then, it will be too lateto create it.

Thus, early awareness can help mold development into a resilient pattern that includes more through-streets, with a focus on functional types that are the most lacking. With good macro-level connectivity in their plans, even if they can only afford half-width construction, or if many segmentsremain unbuilt long after they are needed due to funding constraints, they will at least have an option they can easily activate once funds are available.

In many locations, even creating new collectors to fill in connectivity gaps is difficult. The lack ofalternate routes wide spaces is what pushes unwieldy volumes of traffic onto every available roadway. Dealing with problems from that past lack of foresight consumes the time of urban planners and engineers, which inadvertently results in the same lack of foresight for emerging areas. This method will enlighten planners and elected officials of the need for more extensive corridor preservation so that future problems can easily be “fixed” before they break.

Areas with too few short-trip facilities have too many short trips on regional corridors. Conversely, too few regional corridors in an area push long-distance traffic into neighborhoods. Both result in massive amounts of accumulated delay. When a lack of adequate network support structure is a significant source of a corridor’s problems, solutions are still possible. These include:

1. **Better use of frontage roads**: There are often opportunities to be realized, such as the potential to install one-way frontage roads, or convert two-way frontage to a wider road.
2. **Complete connections:** Many roads almost connect to other roads, or locations where the pathto connect two roads is 80% unobstructed, could be connected with potentially modest effort.

5.5 Impact on Freight Markets: 7D Freight Supply & Demand Assessment

5.5.1 Data and Overview of Procedure

The method will utilize spatial market and infrastructure data sources within the context of7D variables to enable corridor managers to identify, visualize and pinpoint supply and demand relationships on freight corridors at different levels of scale and complexity, and will be illustrated within the context of a very simpleinter-regional corridor in Iowa. The process will demonstrate how different data layers can be constructed and overlayed to incrementally explore freight market factors as they relate to corridor performance.

Method/Tool	Corridor Management Issue Addressed:
7D Framework for Assessing Freight Environment	**Problem:** Supply chain and goods movements on existing corridor performance insufficiently considered in practice due to lack of applicable calculations to estimate effects of corridor characteristics on travel behavior.
	Summary of Solution: Application of the 7Ds in order to understand freight movement and utilization along a corridor

To begin, the modification of the 7D variables to a freight orientation needs to be established. What each means in the context of the freight conversation is outlined in Table 3. The variables transition from the previous commuter focus to a frame of reference about the freight movements and a supply/demand mentality.

Table 3 7D Freight Variables

D Variable	Freight Meaning/Metrics
Density	Industry clusters and the synergies around supply chain clusters is an emerging field of study. The interplay between population density and e-commerce/home deliveries is an area that could be explored in a corridor context.
Diversity	Freight village concepts in Europe have sought to offer modal options and a variety of freight support services at the intersection of long-haul and last-mile corridors. Many European freight villages required subsidies to drive these developments. In the U.S. multimodal logistics centers are a close cousin.
Design	Freight design measures consider pavement, bridge, and geometric factors for accommodating large trucks and depending on the local economy, over-weight or over-size vehicles. In urban areas, agencies have historically sought to keep large trucks out of neighborhoods by designating and designing specific routes for trucks.
Destination Accessibility	For freight destination accessibility is viewed from a supply chain perspective and the availability to reach important domestic and foreign trade markets through competitive alternatives. Captive shippers pay higher rates. Access to equipment canalso impact accessibility. For example, specialty grain shippers in the Midwest often have difficulty accessing 20-foot intermodal containers required for moving grain on truck, rail, and ship to access export markets.
Distance to Alternatives	The private sector view of this metric might be better stated as time or cost to alternatives. Examples abound of "build it and they will come" projects seeking to use freight alternatives to foster economic development. Many of these projects fail or fallshort of expectations because key industry supply chains are not well understood. *Freight fluidity* is a growing area of performance measurement on this topic.
Demand Management	Demand management for freight also focuses on costs – primarily for labor and fuel. Moving deliveries to non-peak hours in urban areas allows a driver more deliveries inthe same amount of time, using less fuel. To be effective on a broad scale requires shippers and receivers to alter staffing patterns, which may increase their costs.
Demographics	Hours of service (HOS) and workplace environment have become driving factors in the trucking industry. Many trucking firms have adopted regional market strategies that enable truck drivers to complete their routes in a single day (per HOS regulations) and return home each night.

From here, the application of the variables turns to the relationship of each to supply and demand characteristics. Does the variable talk about the supply side of capacity and accessibility potential, or is it on the demand side of the conversation where quantity and characteristics of the market served by the corridor influence the outcome? Table 4 separates the variables into supply or demand and gives an example of what type of indicator could be utilized by each.

Table 4 7D Freight Indicators

D Variable	Supply/Demand	Potential Indicator
Density	Demand	Concentration of freight activity along a corridor.
Diversity	Demand	Types of industries found around a corridor. Review of industry mix.
Design	Supply	Design profile of the roadway and characteristics needed for a truck route
Destination Accessibility	Supply	The ability to arrive at a destination. This means the drivetime capabilities (with or without delay factors) but also looks at the availability of options for freight movement.
Distance to Alternatives	Supply	The destination to other modal locations. Similar to destination accessibility, the options to change modes and how the freight is moved.
Demand Management	Demand	Opportunities for shippers to find alternatives or modifications to delivery needs. This is more of a qualitative measurement as it looks at policy potentials that influence demand.
Demographics	Demand	A workforce question of how many people are in a given area or how far they need to travel to a workplace.

5.5.2 Data Inputs

Given this overview of potential indicators, the data needed can vary by corridor. The listing provided here is a summary of general thoughts around the process and the example used in Iowa for this report but has the flexibility to include more detail or analyze specific aspects and industries along a corridor. This means not only the 7Ds of fright in general, but if the data is limited to a specific NAICS code then the scoring is reflective of the corridor's impact on that market profile.

D-variable analysis requires spatial data. The following list is indicative of the data needed but isnot limited to this list. Universal datasets were used in the study, but agencies may have more detailed sources that can be utilized in order to reflect corridor assessments.

Data inputs include:

1. Travel demand models
2. Asset performance data, such as pavement data and bridge condition
3. Industry profiles and spatial locations of distribution centers, manufacturing plants, or warehouse facilities.
4. Modal locations such as port terminals, airports, and intermodal facilities
5. Roadway and bridge design characteristics
6. Demographic information about population and employment

Finally, the tools used in this analysis primarily are through ESRI. This includes ArcGIS desktop, general geoprocessing functions to assess buffers and network connectivity, and ESRI Business Analyst. The latter was used as a resource for information that may be more accessible to some agencies and more detailed than what is shown here.

5.5.3 Computing Corridor Measurements

The process to compute statistics for the 7Ds will be discussed along with the example applicationin section 5.6.4. But first section 5.5.3 will describe outputs of the process and where this method can be most helpful.

Outputs

In determining the report card process, for a corridor under analysis, each variable will receive a good, fair, or poor rating. This reporting method will illustrate that a variable within the corridor alignment is more favorable than the average or comparative standard receives "good", a "fair" designation means it matches that average, and a "poor" is below average for that standard or performance criteria.

Some standards discussed parallel existing performance criteria. For example, given the role of truck traffic in shaping the timing of preservation treatments (and associated other changes that may be bundled into such projects), it makes sense to review the pavement conditions of the corridor. This performance breakdown is established by each state. Other variables will be poised against national averages. The point will be to have a score card for the corridor's freight activity that is comparable to relative data and establishes a standard that canbe quantifiable and reviewed over time. Table 5 shows an example result.

Table 5 Example 7D Freight Scorecard

D Variable	Corridor Grade
Density	**Good**
Diversity	**Fair**
Design	**Fair**
Destination Accessibility	**Poor**
Distance to Alternatives	**Poor**
Demand Management	**Fair**
Demographics	**Good**

5.5.4 Application Case Example

The example used for this effort will be I-80 through Iowa. Figure 46below shows the existing state network and highlights the I-80 Corridor (in red) as it runs East-West through Iowa between the neighboring states of Illinois and Nebraska. The example will be broken out by variable for discussion. To assess the quantifiable data around the corridor, a 20-mile buffer was used as a catchment area. The buffer is the highlighted area around the I-80 corridor.

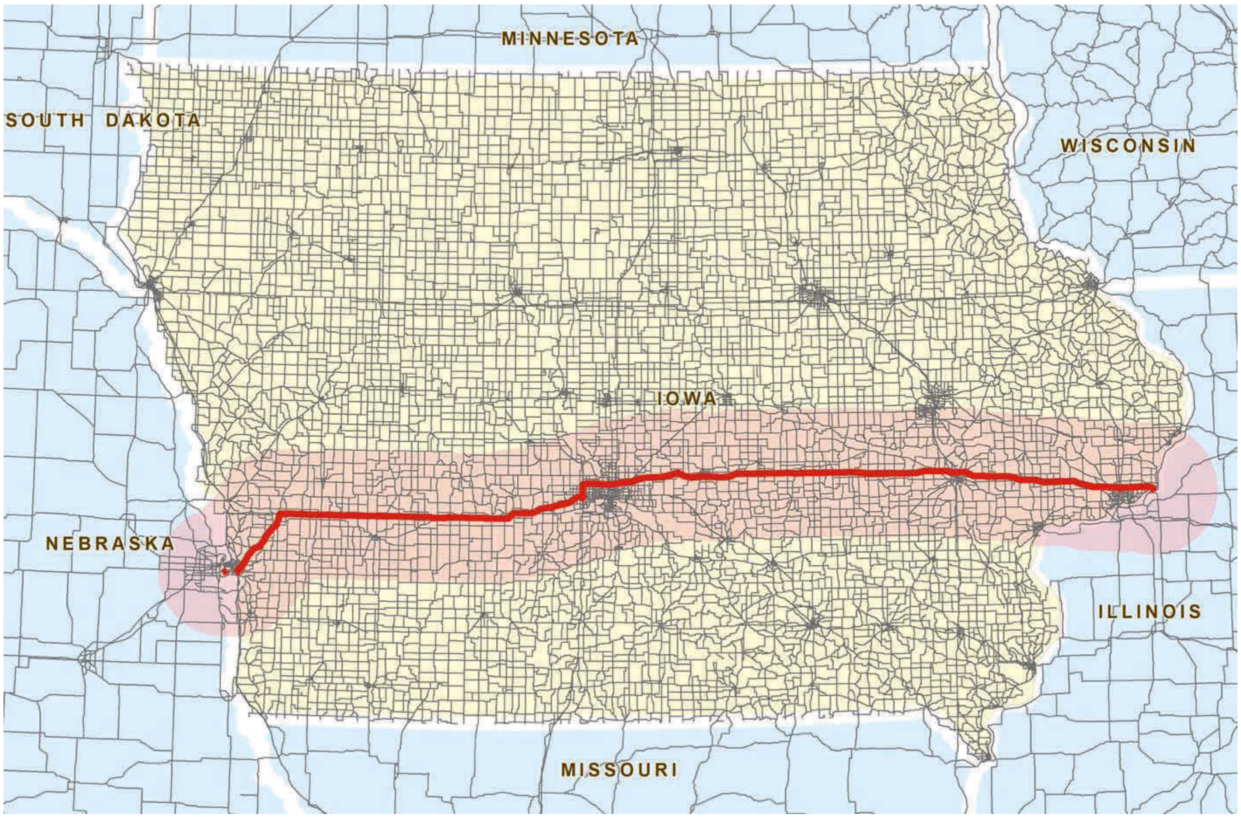


Figure 46 I-80 Corridor

5.5.5 Density

The Density of industrial action as a whole is a comparison of establishments within the buffer area compared to the entire state. Using ESRI Business Analyst, the buffer area includes 83,705 businesses. This is 56 percent of the entire 149,209 businesses in Iowa. So, dividing the 100% potential into thirds according to good/fair/poor, the freight density score for Iowa I-80 is “fair” (asit falls within the 33%-66% range).

As mentioned, this could also reflect industry-specific measures as well. The concentration of freight activity along the corridor for a specific industry is assessed through a location quotient of the various industry. Location Quotient equation is performed by dividing the total annual average employment for each industry by the total covered employment in all industries in the regional market. These are the regional industry concentration values. Finally, if the regional industry concentration is divided by the corresponding national industry concentration, a national comparison is derived. This quotient can be the number of businesses or the total employment, depending on available data, and could use either NAICS or SIC codes for the industry identification. This data is also reported to the U.S. Census for a state comparison to the nation.

Using this methodology for I-80 and highlighting a single industry type – Agriculture, Forestry, Fishing & Hunting, NAICS code 11 – it shows that this industry density is "good". This is assessed through a comparison of the businesses within the buffer area to the state average. Table 3 reflects the analysis results.

Table 6 I-80 Analysis Results

Area	NAICS 11	Total	Percentage
I-80 Buffer	842	83,705	1.0%
Iowa	938	149,209	0.6%
Nation	25,593	7,912,405	0.3%

Reviewing this, the I-80 Corridor is above average when compared to the state percentage. Therefore, using the same good/fair/poor methodology, I-80 would have a "good" for the industrytype of Agriculture, Forestry, Fishing & Hunting. This shows the potential importance of the corridor in this specific industry within Iowa.

5.5.6 Diversity

Fright diversity can be captured through assessment of point to data reflecting the business locations. The industry mix is understood as the diverse group of industries served by a corridor. Considertion of "diversity" or a freighit corridor entails considering the industry mix and the range of business users. By considering the location of industreis on the corridor, managers can potentially work to help industries co-locate with supply-chain partners reducing VMT and other transportqtion costs. Applying this logic to I-80 entails considering similar business locations across Iowa and mapping out I-80's industry mix to consider leveraging the diversity of business types served. Figure 46 shows individual locations across Iowa of similar farming activities, such as grain elevators, ethanol and biodiesel plants, and ethanol transloading facilities orstorage locations. Figure 47 shows that same information in a density setting where the darker the purple, the heavier the concentration of similar activities exist.

Figure 47 Individual locations

Figure 48 Heat Map

Using the heat map in Figure 47, the ability to identify supply chain effort to co-locate in similar areas, in this case, Des Moines and Davenport along the I-80 corridor, allows the user to assess corridor utilization or where improvements may be needed. For the scoring of this D variable, an evaluation of similar industries would need to be established. Then the accumulation of segment lengths are coded using ArcGIS tools with the heat map scoring. The greater the score, the more diverse the corridor is in terms of businesses.

5.5.7 Design

Design is the type of the supply variable. Aspects reviewed here might cover the roadway characteristics of the corridor or asset performance. An example of this that is in use currently is in the Atlanta Strategic Truck Route Master Plan (ASTRoMaP)2. This effort was a follow-up recommendation from the Atlanta Regional Freight Mobility Plan (2009) to ensure that truck trafficis directed to roadways whose physical and operational characteristics can effectively accommodate truck traffic. The evaluation criteria use the following attributes, in order of influence from least (1) to most (10):

1. Functional Classification
2. Level of Service
3. Lane Width
4. Posted Speed
5. Truck Volume
6. Shoulder Width
7. At-Grade Crossing Presence
8. Bridge Shoulder Width
9. Bridge Posted Weight
10. Bridge Minimum Vertical

The result generated a composite score that could be determined for each segment. The scores helped identify the corridor's improvement needs to make sure the corridor was uniform in its design to accommodate truck route movements.

This design aspect leaves out the pavement or bridge condition performance on the corridor. This attribute could be incorporated into a similar evaluation criterion, given the target-setting requirements that the DOTs must establish and maintain. Per Iowa DOTs 2018 Infrastructure Condition Evaluation (ICE) report and associated data, the pavement condition index along I-80 is ingood condition overall. Scores range from 40 to 98 on the IDOT normalized PCI scale, with an average of 87. Figure 49 illustrates the pavement performance scale, with red (> 40) as poor pavement and green (< 90) as good.

[2] https://atlantaregional.org/transportation-mobility/freight/atlanta-strategic-truck-route-master-plan-astromap/

Figure 49 PCI per pavement segment of I-80

For the I-80 corridor, incorporating current pavement conditions, the score can be evaluated in thesame composite calculation method. Theoretically, this would show the overall composite scoring of the segments, as averaged up to the overall corridor, which would be used on the corridor scorecard. Similar to other functions, there is the ability to leverage other data sources in this calculation, such as IRI, Bridge Condition, Volume-to-Capacity Ratios, and Bike Lanes.

5.5.8 Destination Accessibility

The methodology to review the accessibility of destinations for freight has similar methods included in access density, connectivity, and truck parking. The efforts are outlined in the previous Section 5.2 Impact on Development Readiness: Master Architecture & Managing the Corridor SystemBlueprint.

5.5.9 Distance to Alternatives

This measure is a distance to other modal locations. In an effort to capture the potential for freight diversion from the road, an understanding of distance to air, water, or rail transfer locations is needed. The analysis of a corridor could be done in either time or miles, with a comparison across similar corridors within the state or nation, or a desired time expectation outlined by an agency.

The analysis takes the destination point and determines the travel effort to the nearest access point of the corridor, such as a ramp interchange of I-80. This measure is captured and scored. For this example, the distance to commercial airports with air cargo service was assessed. Figure 49Figure 50 shows the locations (4 total) within the I-80 catchment buffer.

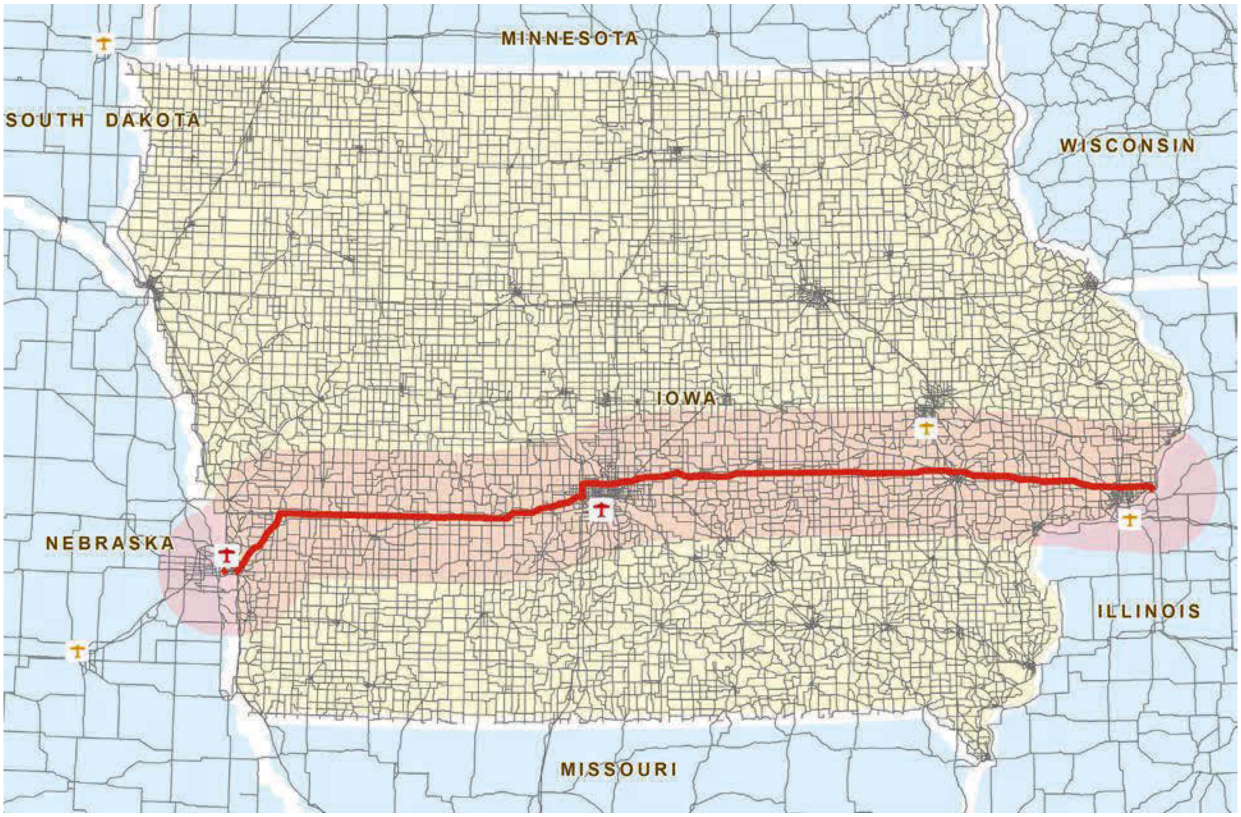


Figure 50 Alternative Modes along I-80

The results show an average of 16 minutes to access these airports for the nearest interstate exit,with the maximum being 19.6 minutes and the minimum being 13.7 minutes. The average drivetime distance is 14 miles, with the maximum and minimum being 15.5 miles and 11 miles respectively. If the analysis shows the comparative average for a similar corridor to be 5 miles and 10 minutes, then it is possible to assess the distance to alternatives in this corridor to be “poor”.

5.5.10 Demand Management

Demand Management is largely a qualitative and policy-oriented variable used to understand what is being done along the corridor to handle aspects such as non-peak hour deliveries. However, there are opportunities to add quantitative information to this variable. There could be some expectationfor a number of alternatives per mile of corridor. This aspect of the measure is primarily oriented toward regional corridors that might utilize other modes or parallel routes. An analysis of time/cost savings for shipments at off-hours could be compared against routine operations to understand the magnitude of savings that could occur and the impacts of potential policies.

5.5.11 Demographics

This variable should be a similar review of demographic data as can be found in other modes. An analysis of employment area catchment with the 20-mile buffer of I-80 shows 1,353,233 total employees. This is 83.3% of the total 1,625,200 employees in the state, across all industry sectors. Based on this coverage, the scorecard would receive a "good" for this variable. Figure 51 is a useful infographic showing specifics for the corridor and illustrates the potential evaluation criteria that could be added to this variable.

Figure 51 ESRI Infographic for I-80 in Iowa

5.5.12 Takeaways

From the example analysis above, the application of the 7D variables can achieve an understanding of freight utilization of the corridor and a means to gauge the activity and economic potential of thecorridor area. Table 7 shows the results of this exercise for I-80 through Iowa.

Table 7 Example 7D Freight Scorecard for I-80

D Variable	Corridor Grade
Density	Fair
Diversity	Fair
Design	Good
Destination Accessibility	Fair
Distance to Alternatives	Poor
Demand Management	Fair
Demographics	Good

5.6 Impact on Communities: 7D Framework and Methods for Assessing the Built Environment

5.6.1 Section 1: Data and Overview of Procedure

Data Inputs

D-variable analysis requires spatial data. Such spatial data includes TAZs with socioeconomic information, street networks, transit stops, land-use (at the parcel level), and travel times among TAZs using both automobile and transit.

Employment Data

Employment data is needed to help define a general corridor influence area, as described in the methodology below. This data is obtained from the US Census Bureau's Longitudinal Employer-Household Dynamics (LEHD) database. Specifically, LEHD Origin-Destination Employment Statistics data (LODES) are used. This dataset, which can be downloaded by state, contains employment data at the census block level. For this analysis, the location of jobs is needed, so LODES7 Workplace Area Characteristics data is used.

Census Blocks

Census blocks (in shapefile form) are also needed to help define a corridor influence area in this methodology. These can be obtained readily from the US Census Bureau. Because LODES7 is enumerated using 2010 census blocks, the 2010 census blocks should be used for mapping the data.

Method/Tool	Corridor Management Issue Addressed:
7D Framework for Assessing Building Environment	**Problem:** Build environment effects (7D) on corridor performance insufficiently considered in practice due to lack of uniform reporting of character D-variable characteristics to permit ranking and indexing.
	Summary of Solution: Apply a standard definition of D-variables developed through peer-reviewed research to consider land-use characteristics of corridors, for indexing and comparison.

Procedure for Calculations and Ranking

D-variable Calculations

In order to calculate the d-variables for corridors, the following steps are required:

1. Define what constitutes a corridor.

Up to the time of writing, the D-variables have never been used to define corridors. They have been used in the past to examine the built environment's influence on travel behavior for a metropolitan region at large and travel behavior at individual developments (such as TODs and mixed-use developments), but never have the D-variables been used for corridor management. This requires defining what is to be the "corridor influence area" or the area most directly influenced by the corridor. This question is not an easy one to answer, and there may be multiple ways to define a corridor influence area depending on different contexts and purposes. In this methodology, however, employment clustering is used to define a corridor influence area. Employment can be mapped by joining LODES7 data to a census block shapefile. For interstates and other controlled-access highway corridors, map all employment (jobs in most sectors tend to cluster near highways in American cities). For lower-level corridors, such as arterials, map only select employment sectors that cluster near arterial streets, such as retail, accommodations, and food service. Determining which sectors to map for a corridor type may take some trial and error depending on local contexts. Use the mapped employment data to visually determine an approximate buffer distance from the street where jobs typically cluster (e.g., 0.5 miles). This distance is the general corridor influence area.

2. Define corridor segments.

In order to rank corridor segments, they must be compared to other similar segments. Determine how to divide up all comparison corridors in the metropolitan area. This can be simple. One easy method is to define segments as the length of the corridor between interchanges or intersections with other corridors of similar functional class. In regions with relatively few interchanges between corridors of similar functional class, an alternative method would be better so that you have enough segments to make comparisons. In this case, divide corridors into segments in a way that makes sense with the local context.

3. Buffer corridor segments.

Using the buffer distance determined in step 1, create shapefiles of the corridor influence area foreach corridor segment. This step can be made a bit easier if existing corridor shapefiles can be obtained, such as a shapefile of highways already broken up into useable segments. If such data is available, download it. If not, manually create a shapefile of corridor segments in ArcMap.

Then, conduct a buffer analysis in ArcMap using the corridor influence area determined in step 1.After the buffer has been completed, create two new fields in the resulting shapefile: *GEOID* (short integer) and *name* (text). In an edit session, assign each segment buffer a unique numerical identifier (type this in the *GEOID* field) and a short description of the corridor segment that corresponds with the buffer (type this in the *name* field).

4. Conduct D-variable Analysis.

Using the resulting buffer shapefile from step 3, analyze the D-variables for the corridor buffer areas. For density, the ArcGIS model outputs data on the number of jobs and people in each bufferarea (separate measurements). Calculate activity density as follows:

$$Activity\ density = \frac{population + jobs}{sq.mi.}$$

For diversity, the Utah model outputs the area of land devoted to each of three categories: residential, commercial, and public. In Excel, calculate the proportion of each corridor buffer used for each land-use type. Then, use the following equation to calculate land-use entropy according to Ewing et al. (2015):

$entropy =$

– !"#$%"&'$() #+(!"*-.(!"#$%"&'$() #+(!")12344"!2$() #+(!"*-.(2344"!2$() #+(!")1567)$2 #+(!"*-.(567)$2 #+(!")

-.(8)

For a design variable, either count the number of 3-way intersections and the number of 4-way intersections in each buffer area or use GIS software to do so. Calculate the percentage of 4-way intersections and the intersection density as follows:

$$\% \; 4 \; way = \frac{\# \; 4 \; way \; intersections}{total \; \# \; intersections}$$

$$Intersection \; density = \frac{total \; \# \; intersections}{sq.mi.}$$

For destination accessibility, select the Traffic Analysis Zone that best presents the buffer area of each corridor. Using a travel-time skim output from a travel demand model, find each buffer area's matching TAZ number in the job accessibility spreadsheet, and copy and paste the data for the number and percent of jobs accessible in 10, 20, and 30 minutes by car and number and percent of jobs accessible within 30 minutes by transit.

Finally, for distance to transit, count the number of transit stops in each buffer area. Calculate transit stop density as follows:

$$transit \; stop \; density = \frac{\# \; transit \; stops}{sq.mi.}$$

Calculation of each D-variable will result in a quantitative output value that can be used to describethe built environment of the corridor segment buffer area.

Ranking Corridor Segments

1. Group corridor segments into similar categories.

This step accounts for the variety in corridor segments throughout a metropolitan area. The way corridor segments are grouped may be different depending on regional context and purpose of analysis. As such, there is no "one-size-fits-all" answer to the question of how to group corridors. One possible method, as demonstrated below, is to group corridor segments by the highway "ring" of the metropolitan area in which they exist. This method works well in the case of analyzing I-45 in north Houston because the project segments are broken up in a similar fashion.

2. Rank study corridor segments using an index.

To see how a corridor segment in question ranks against its peers, use a simple min-max index togive it a ranking. This can be accomplished using the following equation

$$I = \frac{V - v_{4\$\&}}{v_{4(9} - v_{:;-}}$$

where I = index score; V = study corridor value; v_{min} = minimum corridor value; and v_{max} = maximum corridor value. The resulting value for I indicates how the corridor compares to the lowest and highest value corridors in the comparison group for a given D-variable measure.

5.6.2 Outputs D-variables

The calculation of D-variables will provide a set of numbers which represent quantifications of the built environment within the impact area of each corridor segment. The desired targets for each D- variable will depend highly upon the goals and values of the organization(s) managing a corridor.

The D-variable framework, however, does present an opportunity for corridor managers to go above and beyond the traditional corridor performance measures. Corridors are often treated as if they exist in a vacuum when in reality they have a close connection with the land around them.

The D-variables enable practitioners to understand the interactions between transportation and land-use in a way that is not traditionally done. Especially in consideration of freeways and large arterials, transportation practitioners may find more success in serving the needs of communities through which a corridor runs by using the D-variables.

5.6.3 Indices

The index values of corridor segments can be used to compare a particular corridor segment to a group of peer segments. As with the D-variables, the results of indexing corridor segments can best be presented in a table, as shown in the next section where this methodology is applied to the segments of the North Houston Highway Improvement Project. Alternatively, corridor segments could be mapped along with their index values displayed on the map. A map would have the advantage of giving geospatial context to each corridor segment.

Using indices, comparisons can be made using a group of corridor segments from one metropolitan area or multiple, although practitioners should exercise caution when determining which corridor segments in other metropolitan areas compare to corridor segments on their own. Since each city's corridor network is different, using a group of corridor segments from multiple metropolitan areas may not be the best option; quantifying corridor segments in multiple regions would also be very time-consuming. However, an advantage to including corridor segments from multiple regions in a corridor analysis is the larger sample size that can be used to determine a range of minimum and maximum values.

The usefulness of indexing may vary depending on the corridor management context, although in general, the indexing process offers practitioners a simple way to compare an individual segment's D-variables to others. Like the D-variables, however, there is no established standard index value that corridor managers should aim to achieve. This method is designed as a simple comparison tool with the ability to describe the current reality of a corridor. Local corridor managers should use their best discretion when interpreting index data.

5.6.4 Application and Case Analysis

In the case of Houston, freeway expansion has become contentious along the two southernmost segments of the project. The City of Houston and community representatives of the areas that would be directly affected by freeway expansion have argued in favor of constraining the freewayto its existing right of way while expanding transit and improving walkability. Since previous research links the D-variables to some of the accessibility and livability goals expressed by the Cityof Houston and its various community partners, quantified D-variables could be used to describe the existing reality in the corridor influence area as well as set goals for the corridor.

The aforementioned steps are applied to the Houston region to quantify D-variables and rank segments of Interstate 45 in north Houston that the Texas Department of Transportation has defined in its North Houston Highway Improvement Project (NHHIP). This project is ongoing, and TxDOT and the City of Houston have had some notable disagreements about what the project should accomplish and prioritize. In the Houston region, highway segments were defined as the portions of each highway between interchanges with other highways. Segments were defined in this manner because the NHHIP broke its three segments up in this manner. NHHIP segments are generally the segments of I-45 from downtown Houston to Beltway 8, with divisions being Houston’s major highway rings, as shown in the following figure. All other segments of highway inthe Houston area are classified as comparison segments based on the highway rings in which theyare included.

An analysis of employment data determined that 0.5 miles on either side of the region's freeways isa reasonable approximation of where employers tend to locate, as shown in the following map.

Based on this assessment, a 0.5-mile buffer was created on either side of the highway segments.

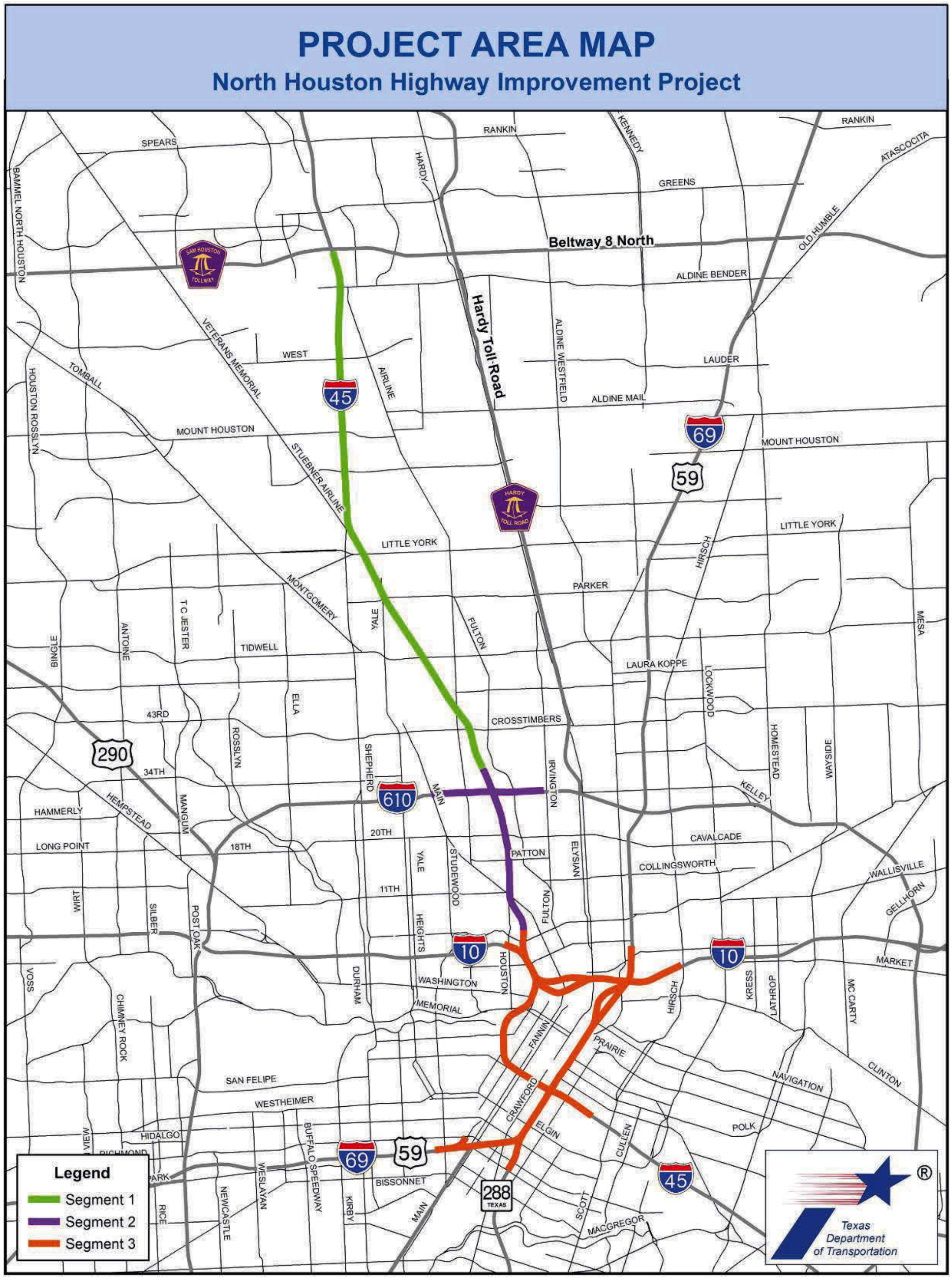


Figure 52 North Houston Highway Improvement Project

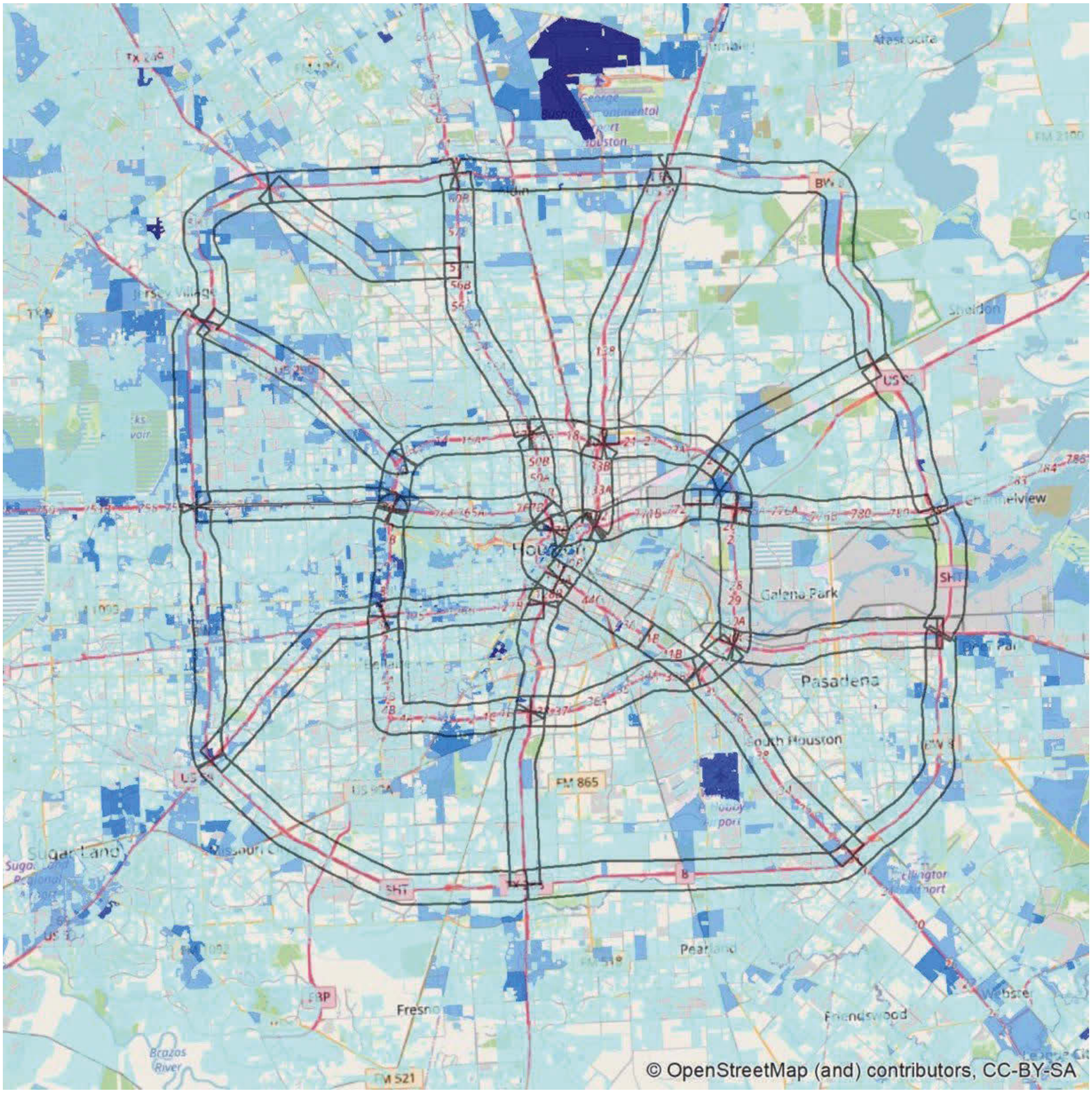


Figure 53 Applying D-variables to Houston I-45 Corridor

The indexing process was then used to score the three NHHIP segments against their peers. Only portions of NHHIP segments signed as I-45 are given an index to remain consistent with how othercorridor segments were defined. The results of this analysis are shown below:

NHHIP Segment	Act. Density	% 4-way int.	Int. Density	LU Entropy	Transit Stop Density (stops/sq mi)	emp10a	pct_emp10a	emp20a	pct_emp20a	emp30a	pct_emp30a	emp30t	pct_emp30t
1	0.40	0.67	0.70	0.86	0.76	0.39	0.39	0.68	0.68	0.88	0.88	0.36	0.36
2	0.27	0.73	0.68	0.82	0.62	0.50	0.50	0.75	0.75	0.92	0.92	0.48	0.48
3	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.92	0.92	0.94	0.94	1.00	1.00

This application of the D-variable methodology in the I-45 corridor in north Houston reveals some key information about the corridor segments that will be reconstructed in the near future that havenot been included in the initial process, at least not to the extent that the City of Houston may prefer. The quantification of the D-variables for each segment reveals built environment characteristics beyond the highway itself that influence travel behaviors. This information could give provide the City of Houston and TxDOT with numerical data to help think about how the corridor may be rebuilt in a way that better serves the community and accommodates the City of Houston's concerns. The D-variables do not tell the full picture, but in general higher values for each D-variable correlate with greater accessibility, and all but the variables related to auto accessibility will likely have a positive correlation with the share of trips made by walking, biking, ortransit.

The index measures for each of the three NHHIP segments indicate how the segments compare to other similar segments (as described above). This information may not be incredibly useful, but it can act as a useful performance metric for the corridor segments. A higher index value indicates that the particular corridor segment performs well compared to its peer segments. In the case of Houston's NHHIP corridor segments, the results are mixed. Corridor segments 1 and 2 perform well in some categories and underperform in others compared to their peers. Segment 3 consistently performs well across D-variables, but segment 3 had fewer segments in its comparison group because the highway ring around downtown has fewer segments than outlying rings. For this reason, segment 3's indices may not be as useful as those of segments 1 and 2. Regardless, TxDOT and the City of Houston could potentially use these indices to help make decisions about corridor improvements on I-45.

5.6.5 Takeaways

Because corridors have not been evaluated in terms of the D-variables before, this methodology provides a new application of the D-variables that can potentially be used to examine corridors. The current paradigm of transportation planning is shifting toward a more holistic approach to corridor planning and management, one which recognizes that corridors do not exist in a vacuum but instead have very close relationships with the land around them. This necessitates a thorough understanding of the built environment within a corridor’s influence area.

The methodology presented here illustrates a way of quantifying the D-variables in a corridor, and this data provides a quantitative description of the built environment. However, practitioners may use this data to understand where their corridors are now and set goals for where they ought to be in the future. Because the D-variables correlate with travel behavior, practitioners may use D- variable data to set goals related to transit use, walkability, and VMT. Practitioners may also wish to think further about what each of the D-variables means within the context of their local built environment.

The indexing methodology presents practitioners with a way to rank corridor segments against their peers. Like the D-variables, the indices do not mean much on their own, but practitioners who calculate these indices may use them to determine whether corridor segments that should be performing similarly are doing so. As such, the indexing method may help corridor managers see just how well a particular corridor is being managed compared to corridors with similar purposes and contexts. Indexing built environment data is a very simple process that can be very useful to practitioners.

Lastly, the D-variable methodology presented here is meant to be flexible. There is no one-size-fits-all way to analyze the D-variables within a corridor, so practitioners following this methodologyshould feel free to adjust the procedure as they see fit. For example, for a certain corridor context, a 1-mile buffer may be preferred over a 0.5-mile buffer. Corridor managers may also wish to analyze arterials rather than highway corridors. Additionally, practitioners may wish to divide corridors into segments in a different manner or create comparison groups differently. Either way, the methodology presented herein allows for this flexibility while maintaining the same basic process of data analysis and calculation. This D-variable methodology is extremely versatile and can be applied to any conceivable corridor D-variable analysis scenario, provided the proper data is obtainable.

5.7 Impact on Technology Utilization: Assessing and TrackingCorridor Technology Profile

Method/Tool	Corridor Management Issue Addressed:
Corridor Technology Profile	**Problem:** Corridor readiness for autonomous/connected vehicles unknown; method to assess readiness unknown; interoperability between existing systems uncertain.
	Summary of Solution: Readiness 'report card' to analyze existing conditions with reference to a benchmark for connected vehicle adoption.

5.7.1 Data and Overview of Procedure

Technology readiness is among the suite of impact methods agencies can employ for effective corridor management. Since technology is a broad topic, this example recipe focuses specifically onConnected Vehicle (CV) readiness. Before diving into details, below is an overview of CV technologyand communications.

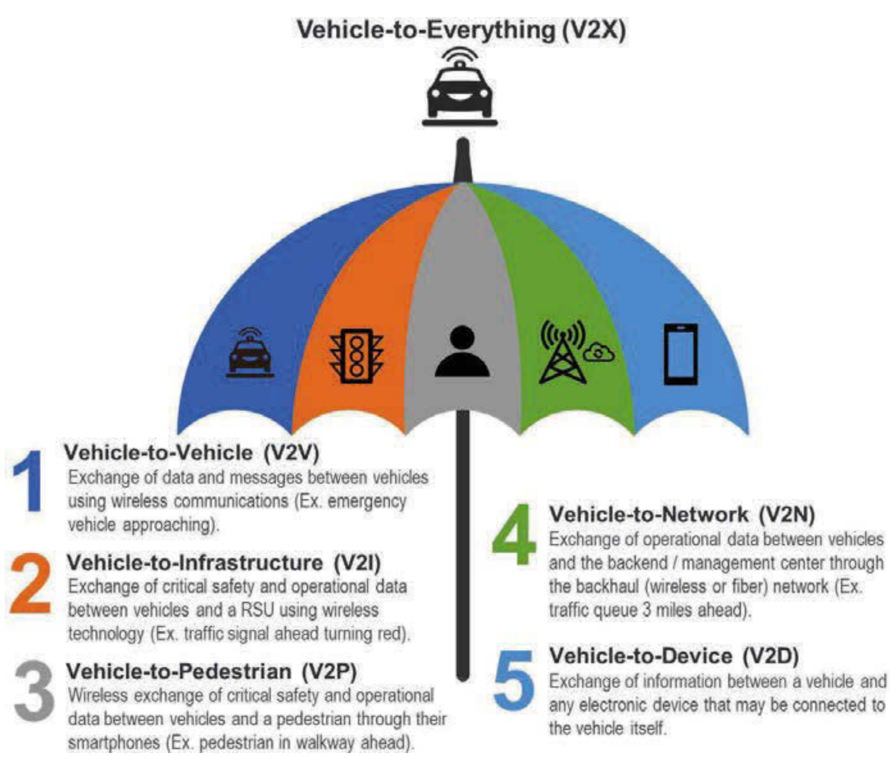


Figure 54 Overview of Vehicle to Everything (V2X)

Ultimately, a corridor should try to achieve the V2X and connecting everything to everything. However, as a starting point for a corridor, the focus should be on Vehicle-to-Infrastructure (V2I), such as traffic signals or roadside units (RSU). This is the focus for the recipe – How do you communicate information from signals and RSUs along a corridor to a vehicle? In addition, how do you receive information from the vehicle to the infrastructure, and ultimately a traffic management center (TMC) or database toinform traffic operations decisions?

Definition

Vehicle-to-Infrastructure (V2I)is the exchange of critical safety and operational data between vehicles and roadside units using wireless technology.

Along with the recipe includes information from a recent case study for the Virginia AvenueCorridor near Hartsfield-Jackson Atlanta International Airport in College Park, East Point, and Hapeville, GA (just south of Atlanta).

Data inputs

The following are hardware and software elements and tools needed for technology readiness:

1. Signal hardware and software inventory, including:
    - Signalized intersection location information: street, cross street, jurisdiction
    - Signal controller information: signal manufacturer, software
    - Signal cabinet information: type, mount, manufacturer, date, auxiliary bay, battery back-up
    - Communication hardware: present (yes/no), type (fiber or cellular communications)
2. Communication protocol with local, regional, and state transportation departments to coordinate interoperability
3. Advanced Traffic Management System
4. V2I Communication Hardware/Software (e.g., Dedicated Short Range Communications (DSRC) or 4G cellular radios)
5. Other CV applications

5.7.2 Procedure

1. Conduct an Inventory of Existing Signals

The first step in preparing for CV technology is assessing the existing signal communication technology if present. This will require a signal technician or engineer to visit each location anddocument the attributes of the signal. They should include the following, at a minimum, in theirtable or report:

- Location information
- Controller information
- Cabinet information
- Communication information

Once this information is collected, a corridor management team or coalition should work together to determine what upgrades or additions are needed at each intersection. It can take some time to procure equipment if not on hand and arrange for installation. The team should also determine the appropriate communicationprotocol to transmit information from the signals to a traffic management or data center. Options include fiber (underground) or cellular (currently 4G). Many corridors have both to create redundancy in the system, using cellular as backup. However, this can become costly if fiber does not currently exist. If a team is facing budget constraints, it is recommended that they explore cellular options as they are quicker to install and less expensive. It should be noted that when costing out cellular routers, there will be a required subscription (similar to a cell phone plan) through a telecommunication company that should be taken into consideration while budgeting.

2. Establish a Communication Protocol with Necessary Entities

There should be proper coordination with local, regional, and state transportation departments, as it is critical to the implementation of CV readiness. Standards should be established in terms of acquiring hardware/software that is interoperable with one another, funding arrangements for hardware and software, roles and responsibilities for installation and maintenance, and required permitting. If there is a jurisdiction or department of transportation that has already established standards, the corridor team should consider whether adopting these standards are appropriate before considering establishing new and unique standards as it increases the risk of interoperability and coordination.

3. Establish a Communication Protocol with Necessary Entities

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4. Advanced Traffic Management System (ATMS)

For V2I, each signal must be outfitted with software that can collect signal information such as the number of vehicle approaches, pedestrian pole activation through push buttons, number of turn phases, etc. It can also notify technicians and engineers of any maintenance issues with any component of the traffic signal system. The collection of information can be communicated back to a data center or TMC to monitor operations and performance. As discussed in Step 2, it is importantthat the team coordinate with other entities to determine if ATMS is being used elsewhere and if there are opportunities to partner on procuring vendors and systems.

Advanced Traffic Management Systems (ATMS) provides a top-down approach to mitigating traffic congestion in a real-time format. Through the collection of real-time data from roadside units and traffic signals, ATMS creates a central hub to process data and provide real-time solutions to improve regular traffic conditions, as well as respond to unique traffic incidents. ATMS can be deployed to monitor and improve traffic conditions at the intersection, corridor, or area level.

Several performance measures can be created from installing the data collection software outside of the CV application(s). GDOT created a dashboard of signal performance that they can monitor for overall corridor management, such as:

- Vehicle detector disruptions
- Pedestrian detector disruptions
- Closed Circuit Television (CCTV) availability
- CV radio disruptions
- Traffic volumes
- Throughput

5. V2I Communication Hardware/Software

Once traffic operations data is being collected through the ATMS, the team can start thinking abouthow to broadcast this information to CVs. There are currently two types of broad-casting radios 4G LTE cellular radios or Dedicated Short Range Communication (DSRC) radios. This radio must be installed to provide communication between the signals (infrastructure) and CV. DSRC and cellular radios have varying benefits, and while they cannot operate simultaneously without interference (yet), it is recommended that when funding allows, to install both radios at each location to allow for a wider fleet of vehicles to receive the signal information, such as phasing and timing (SPaT) information. In the future, 5G will be available and cellular routers may need to be updated to accommodate the quicker speed and reliability. Therefore, there is a risk of installing 4G LTE cellularrouters in the near term as 5G is on the brink of becoming widely available. Once this step is complete, the signals are CV ready and can broadcast traffic information to CVs and collect information from the vehicle to help inform engineers and technicians on traffic operation decision-making.

6. Other CV Applications

This step is “the garnish” for the recipe. Once the communication radio(s) and ATMS software are installed, the signal is CV-ready. However, there are other applications available to transmit to CVs if desired. These other capabilities will require additional sensors either at the traffic signal or between signals. An entire list of applications is available through the Federal Highway Administration website and include safety, environment, weather, mobility, agency information and smart roadsides.[195] Adding these components to the system gets the corridor closer to the V2X, everything connected to everything concept. There are few corridors that have achieved this level of connectedness. Vehicle manufacturers have announced fully connected vehicle fleets starting in2022 models (fall 2021) and it is anticipated that V2I and V2X will grow exponentially following those fleets.

> The Glance Preemption and Priority System is an application that utilizes cloud-based soft-ware to integrate cellular, radio, and GPS. The Glance system uses both in-vehicle and intersection controller hardware units, which have all built-in cellular, GPS, and radio capabilities. These hardware units communicate with Glance's cloud-based software, which is available via a web-based and mobile application. The Glance software provides the means for real-time tracking and adaptive preemption of emergency vehicles by end-users, using data and dynamic communication to clear traffic and increase intersection safety.[6]

Advanced Traffic Management Systems

Advanced Traffic Management Systems (ATMS) provides a top-down approach to mitigating traffic congestion in a real-time format. Through the collection of real-time data from roadsideunits and traffic signals, ATMS creates a central hub to process data and provide real-time solutions to improve regular traffic conditions, as well as respond to unique traffic incidents.As ATMS can be deployed to monitor and improve traffic conditions, at the intersection, corridor, or area level.[196]

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- Pedestrian detector disruptions
- Closed Circuit Television (CCTV) availability
- CV radio disruptions
- Traffic volumes
- Throughput

[195] "CV Pilot Deployment Program," Intelligent Transportation Systems - CV Pilot Deployment Program, accessed October 28, 2021, https://www.its.dot.gov/pilots/cv_pilot_apps.htm.

[196] http://www.umtri.umich.edu/our-focus/advanced-traffic-management-systems.

5.7.3 Outputs

Following implementation of signal communication technology and infrastructure, ongoing corridor management, monitoring and reporting is possible. An appendix provides a 'report card'questionnaire to assess CV readiness.

5.7.4 Application Case examples

Application Example: A signal inventory was completed for the Virginia Avenue Smart Corridor Study. Table 1 shows the results of the inventory, including information about the signal locations, controller,cabinet, and communication. On the Virginia Avenue corridor, fiber communication technology was inplace at some signals but not yet connected. On others, no communication capabilities were available.It was also determined that two of the ten traffic cabinets (Rainey Drive and Doug Davis Drive) were outdated and would not support the necessary communication software for CV application

Main Street	Side Street	Jurisdiction	Controller		Cabinet						Communication	
			Manu-facturer	Software	Type	Mount	Manu-facturer	Date	Aux Bay	Battery Backup	Present	Type
Main Street	Howell Slade Circle	College Park	Econolite	Siemens/ TACTICS	332	Concrete Base	Safetran	---	No	No	No	N/A
Virginia Avenue	Madison Street	College Park	Econolite	Siemens/ TACTICS	332	PreFab Base	Safetran	---	No	No	No	N/A
Virginia Avenue	Harrison Road	East Point	Intelight	Siemens/ TACTICS	332	PreFab Base	Intelight	2013	No	No	No	N/A
Virginia Avenue	I-85 SB Ramp	GDOT	McCain	MaxTime	332	PreFab Base	McCain	---	Yes	Yes	Yes	4G
Virginia Avenue	Bobby Brown Parkway	East Point	Intelight	Siemens/ TACTICS	332	PreFab Base	Intelight	2013	No	No	Yes	Fiber / Not Connected
Virginia Avenue	Norman Berry Drive	Hapeville	McCain	MaxTime	332	PreFab Base	McCain	---	Yes	No	Yes	Fiber / Not Connected
Virginia Avenue	International/ Delta	Hapeville	Safetran	Siemens/ TACTICS	332	PreFab Base	Temple	2001	No	No	No	N/A
Virginia Avenue	Rainey Drive	Hapeville	Transyt 1880E		NEMA/ 8 Phase	Concrete Base	Transyt	1984	N/A	N/A	No	N/A
Virginia Avenue	Doug Davis Drive	Hapeville	Eagle	Siemens/ TACTICS	NEMA/ 8 Phase	Concrete Base	Eagle	1992	N/A	N/A	No	N/A
Virginia Avenue	S. Central Avenue	Hapeville	Siemens	Siemens/ TACTICS	332	PreFab Base	Temple	2010	No	No	No	N/A

Exhibit 8 Traffic Signal Inventory Example

Source: Virginia Avenue Smart Corridor Study, Aerotropolis Atlanta Community Improvement Districts, 2019

Application Example: Following the inventory, the cities began coordinating with the Georgia Department of Transportation to discuss options for upgrading signals for CV-readiness. GDOT had established their statewide standard and was in the process of updating communication software andhardware across the state, including corridors that were off the state route network at no cost to local cities. GDOT was able to use their on-call vendors to upgrade the two traffic cabinets and install 4G cellular routers at all the signals for communication back to the traffic management center and to a data center.

Application Example: After a meeting with the Georgia Department of Transportation (GDOT) as part of the Virginia Avenue Smart Corridor Study, it was determined that GDOT has a statewide license for Intelight's MaxTime and MaxView software that is used for smart signal timing and remote access through a web browser. MaxTime is the local intersection software that collects the information which is transferred to the ATMS (MaxView) in which engineers and technicians can access remotelyto adjust and troubleshoot issues. Like the 4G cellular radios, GDOT installed the software at no costto the cities and provided training sessions on how to utilize the web platform.

Figure 55 Georgia Department of Transportation Traffic Management Center

Source: http://www.dot.ga.gov/AboutGeorgia/Pages/GDOTAnnouncementBlogDetails.aspx?postID=1183

North Avenue in Atlanta serves as a major traffic corridor for vehicles, pedestrians, and transit. The North Avenue Smart Corridor project is a "living lab" for Intelligent Transportation Systems (ITS).

Using adaptive sensor systems, which include video detection and vehicle-to-infrastructure communication, signals at intersections can prioritize emergency vehicles, transit, and pedestrian and bicycle traffic. As a result, the North Avenue corridor has seen a 20-35% reduction in collisions, as well as a six-second savings by emergency vehicles per intersection due to signal preemption.[4]

Application Example: Separate but related to Virginia Avenue, GDOT in partnership with local cities and the Metropolitan Planning Organization (Atlanta Regional Commission [ARC]) are beginning a CV program called CV1K. In the first year of the program they plan to outfit over 1,000 signals across Metro Atlanta with DSRC and 4G LTE cellular radios (includes all 10 intersections along Virginia Avenue). This partnership allows the cities to leverage federal funding to install radios as a much lower cost to the cities. The average cost to outfit each signal is approximately $10,000, in which the local city is responsible for 20% of the cost, or $2,000.

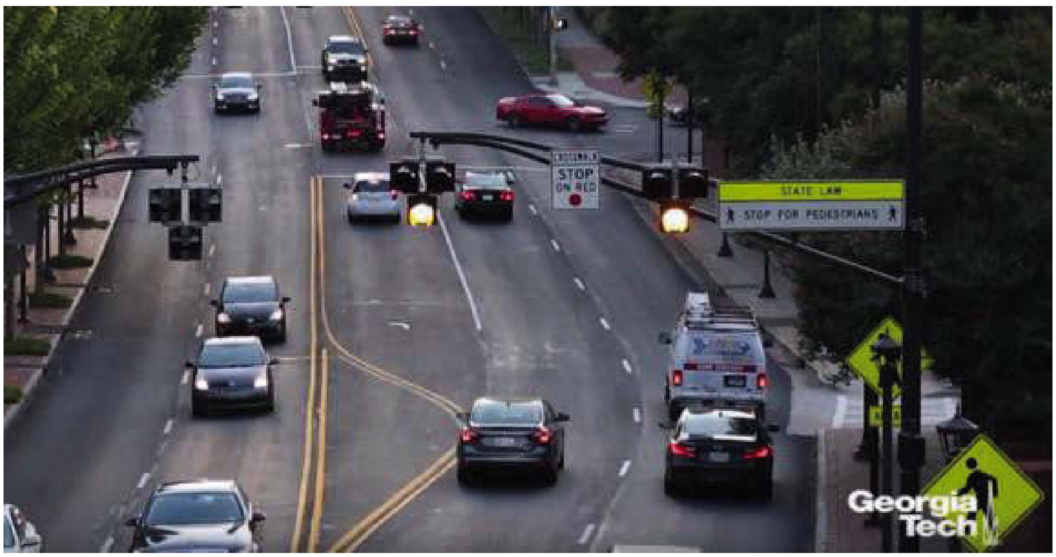


Figure 55 Renew Atlanta North Avenue Smart Corridors

*Source:*http://dev.ipat.gatech.edu/research/smart-cities-and-inclusive-innovation/north-avenue-smart-corridor

Application Example: The Virginia Avenue Corridor, led by the Aerotropolis Atlanta Community Improvement Districts, underwent an evaluation for other technologies that may be useful and applicable for the corridor. Some of the other connected technologies include rapid flashing beacons for pedestrians, transit-pedestrian warning systems, bike signal detection, and autonomousshuttles. Following the Smart Corridor Study completed in fall 2019, the project sponsor and local cities began implementing a strategy to test these technologies through a pilot program. They are currently in the procurement process.

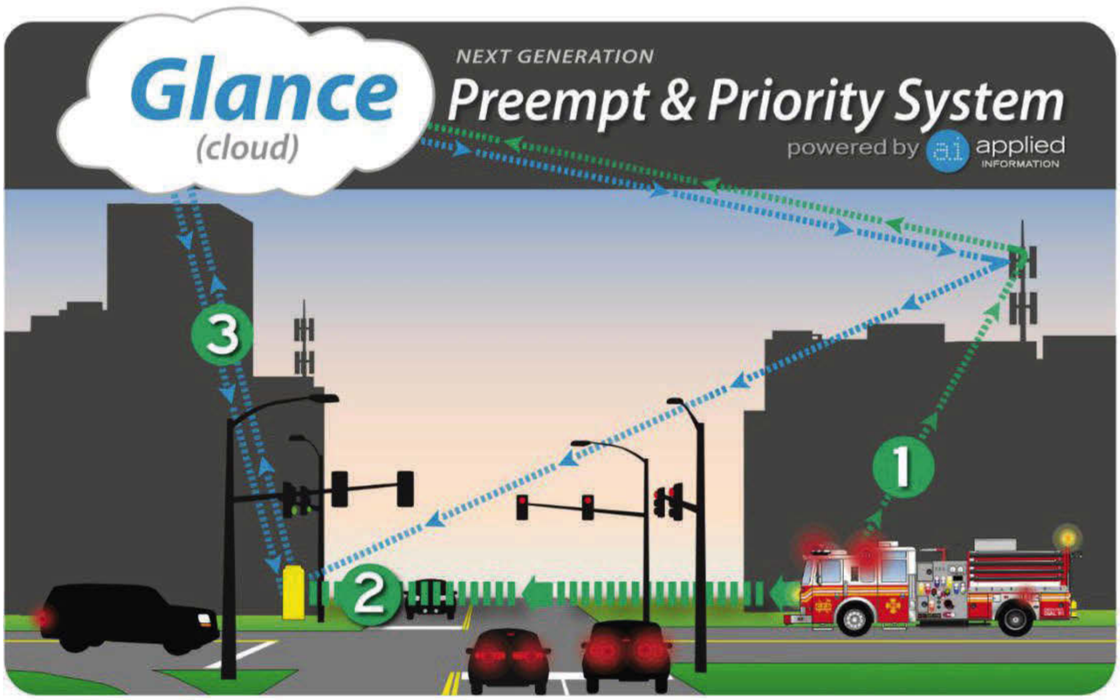


Figure 56 Applied Information Emergency Vehicle Pre-Emption8

Source: https://appinfoinc.com/solutions/v1-preemption-page/

Application Example: Launched in 2018, GDOT has implemented Measurement, Accuracy, andReliability Kit (MARK 1) to improve transportation systems management and operations for thestate of Georgia (Figure 57: GDOT MARK 1 Dashboard). *MARK 1 serves as an Automated Traffic Signal Performance Measure (ATSPM), negating the need for manual reporting for Regional Traffic Operations Programs. MARK 1 consolidates real-time data from traffic controllers and vehicle probe data into advanced signal and corridor-wide and performance metrics. These performance metrics are available at the monthly and quarterly level for each Regional Traffic Operations Program corridor in a publicly- available website.As a result, the MARK 1 program has saved approximately $250,000 annually, saved hundreds of hours in development, and reduced redundancy.*[197]

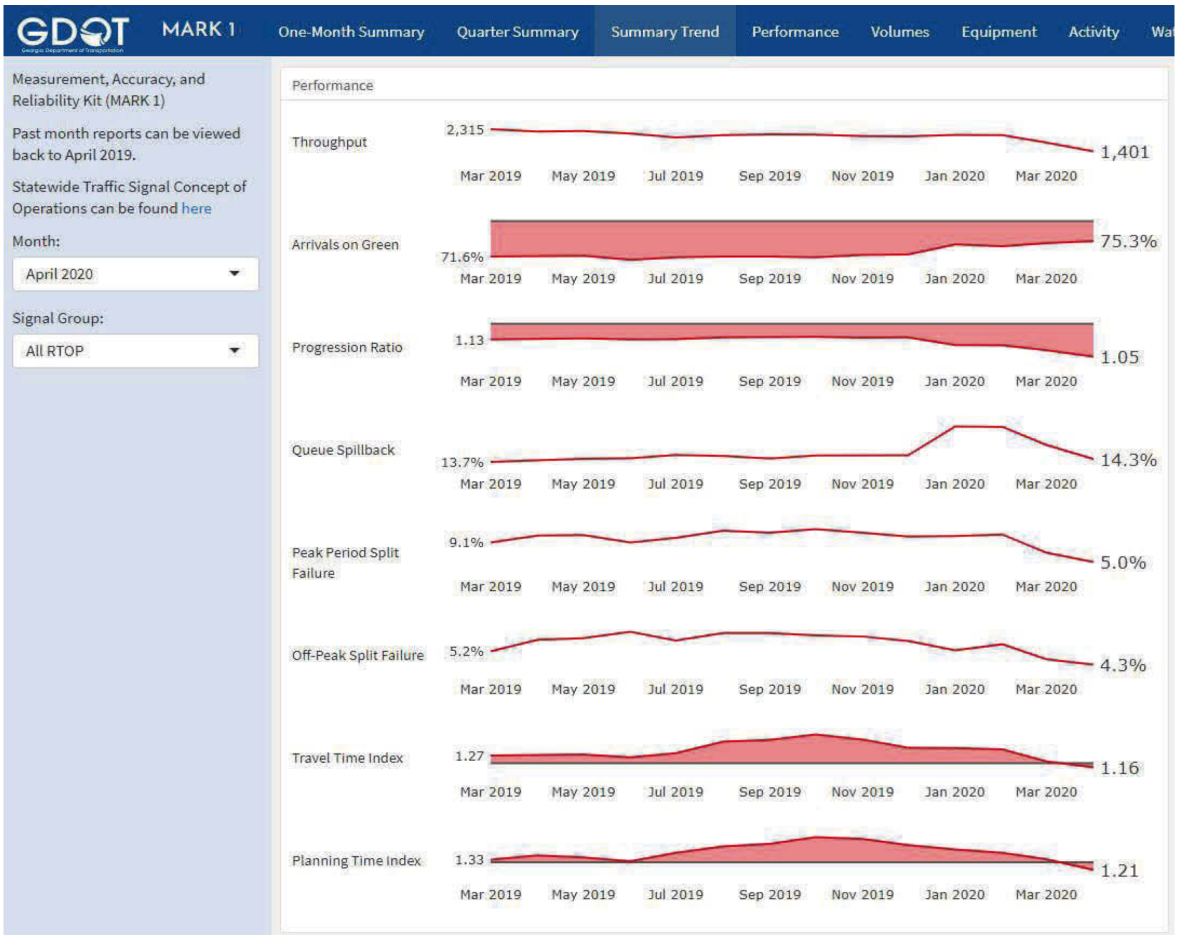


Figure 57 GDOT MARK 1 Dashboard

Source: GDOT, https://atops.shinyapps.io/GDOT_MARK1/#section-summary-trend

[5] https://www.transportationops.org/case-studies/best-use-management-data-improve-tsmo-georgia

[197] Georgia Department of Transportation (GDOT), "Best Use of Management of Data to Improve TSMO in Georgia," National Operations Center of Excellence, January 8, 2020, https://transportationops.org/case-studies/best-use-management-data-improve-tsmo-georgia.

Table 8 Example of corridors with Low, Moderate, and High levels of technology

Application Example of 3 corridors			
	Low	**Moderate**	**High**
1. Does the corridor have traffic signals or roadside units?	No (Worth 0 points)	No (Worth 0 points)	Yes (Worth 1 point)
2. Does the corridor have roadside units that collect or distribute information?	No (Worth 0 points)	No (Worth 0 points)	Yes (Worth 1 point)
3. Are there any communication capabilities along the corridor, such as fiber or cellular?	No (Worth 0 points)	No (Worth 0 points)	Yes (Worth 1 point)
4. How do the signals or roadside units communicate operating information to a traffic management center (TMC), data center, or transportation department?	No communication, we monitor based on physical visits or calls from drivers (Worth 0 points)	I don't know (Worth 0 points)	Fiber (Worth 1 point)
5. If there is communication with a TMC, is a system in place for the TMC to remotely adjust and troubleshoot issues?	No, the signals do not communicate with a TMC (Worth 1 point)	Yes, a TMC receives data from signals and can adjust remotely (Worth 0 points)	Yes, a TMC receives data from signals and can adjust remotely (Worth 0 points)
6. Is the signal hardware (e.g., signal cabinet) or roadside unit hardware and software outdated?	No (Worth 0 points)	Yes (Worth 1 point)	Yes (Worth 1 point)
7. Do you actively manage timing and synchronization through an advanced traffic management system (ATMS)?	Yes (Worth 1 point)	Yes (Worth 1 point)	Yes (Worth 1 point)
8. Do you have the capability to broadcast signal phasing and timing (SPaT) information either through Dedicated Short-Range Communication (DSRC) radios, Cellular, or Satellite?	Yes (Worth 1 point)	Yes (Worth 1 point)	Yes (Worth 1 point)
9. Have you established a standard for broadcasting traffic signal or roadside sensor information?	Yes, our standard is DSRC (Worth 1 point)	Yes, our standard is DSRC (Worth 1 point)	Yes, our standard is DSRC (Worth 1 point)
10. Have you applied any applications for signal pre-emption or signal priority?	Yes (Worth 1 point)	Yes (Worth 1 point)	Yes (Worth 1 point)
11. Have you installed CV Adaptive Signal Traffic Control (ASTC)?	Yes (Worth 1 point)	Yes (Worth 1 point)	Yes (Worth 1 point)
12. Have you installed any roadside units (radio and ATMS) between traffic signals?1	Yes (Worth 1 point)	Yes (Worth 1 point)	Yes (Worth 1 point)

	Low	**Moderate**	**High**
13. Do you provide any electric vehicle charging stations along the corridor? (This can include stations just off the corridor)	Yes (Worth 1 point)	Yes (Worth 1 point)	Yes (Worth 1 point)
14. When was the last time the pavement markings were re-painted?	10 years+ (Worth 0 points)	0-2 years (Worth 3 points)	0-2 years (Worth 3 points)
15. Does the corridor have any midblock pedestrian crossings or unsignaled intersections where flashing beacons have beeninstalled to notify drivers of pedestrians?	No (Worth 0 points)	Yes (Worth 1 point)	Yes (Worth 1 point)
16. If there are bicycles along the corridor, do you provide bicycle traffic signals?	No (Worth 0 points)	Yes (Worth 2 points)	Yes (Worth 2 points)
17. Have you implemented smart streetlights that adjust lighting based on activity and collect real-time information?	No (Worth 0 points)	Yes (Worth 1 point)	Yes (Worth 1 point)
18. If you have parking along the corridor, have you implemented a parking availability/parking meter application?	No (Worth 0 points)	No (Worth 0 points)	Yes (Worth 2 points)
19. If your corridor has curb space that includes parking, have you implemented any dynamic message signs to create a flexible curbside to allow for specific uses during specific times of the day?	This corridor does not have on-street (curb) parking (Worth 1 point)	This corridor does not have on-street (curb) parking (Worth 1 point)	Yes (Worth 1 point)
20. Have you installed any enforcement technologies, such as cameras or license plate readers, for crime prevention or parking enforcement?	No (Worth 0 points)	Yes (Worth 1 point)	Yes (Worth 1 point)
21. Is any technology being used to route trucks along the corridor?	No (Worth 0 points)	No (Worth 0 points)	Yes (Worth 1 point)
22. Is any technology being used to disseminate truck parking availability?	No (Worth 0 points)	Yes (Worth 1 point)	Yes (Worth 1 point)
23. If data is collected on the corridor, are any data sharing partnerships or open data platforms in place?	No (Worth 0 points)	I don't know (Worth 0 points)	Yes (Worth 1 point)
24. Do the local jurisdictions along the corridor have communication and technology in place, such as internet and cellular coverage?	No (Worth 0 points)	No (Worth 0 points)	Yes (Worth 1 point)
	9 points	**18 points**	**29 points**

Category	Threshold
Low Tech	< 10 points
Moderate Tech	10 - 19 points
High Tech	> 19 points

5.7.5 Low

Your corridor scored 9 points, which makes your corridor Low Tech!

You are at the beginning of the journey with lots of opportunity in front of you! If you answered “I don’t know” to more than three questions, you should begin by coordinating with those who workclosely on the corridor, such as traffic operations and public works. You should first focus on the basics for the corridor including communication capability between signals and management centers. If you have that, then think about traffic management software and broadcasting capabilities.

A maximum score is 29. Your corridor needs 1 more point to reach Moderate Tech.

5.7.6 Moderate

Your corridor scored 18 points, which makes your corridor Moderate Tech!

Your adventure has begun! Continue maintaining the technology already installed and begin thinking about other technology features or amenities that may benefit the corridor. Pay attentionto questions you answered no and explore those opportunities.

A maximum score is 29. Your corridor needs 2 more points to reach High Tech

5.7.7 High

Your corridor scored 27 points, which makes your corridor High Tech!

You are technology savvy! It takes time and dedication to outfit a corridor with this technology andyou have accomplished major goals. Continue the great work and share your success so others canlearn from you!

A maximum score is 29. Your corridor has reached the highest level, but there is room to improve!Score another 2 points to reach the highest score.

5.7.8 Takeaways

Self-Assessment

Corridor managers, whether DOTs, local jurisdictions or other agencies can use the self-assessment year over year to monitor the progress of their CV corridor. For example, managers can use the output of their assessment as presentation materials to leadership to illustrate the progress made from the previous year. Further, they can use the questions and responses as a means to develop an implementation and phasing plan for the following year(s). This provides an additional level of documentation that can help keep the agency more accountable for performance and actions. It also provides a paper trail should management teams see an overturn in employees and can clearly illustrate the historical progress made by their predecessors allowing them to quickly get upto speed on activities and next steps. Lastly, it could potentially better position them for discretionary grant funding by providing documentation and a record of progress in grant applications.

CV Readiness Recipe

The recipe provides a step-by-step guide to begin a corridor on its CV journey. This is especially useful for DOTs or local jurisdictions that are entering the CV arena and are not quite sure where tobegin. It can be overwhelming to understand all the components of CV technologies and how to best apply them to a corridor. CV is not a one-size-fits-all, but the recipe provides a basic implementation process that can be easily followed. However, like any good recipe, the steps can be modified to enhance the final product to something that better fits the DOT or jurisdiction's pallet. Outlining a plan and using the case study as a guide can help corridor managers break a complicated process down into more manageable steps and this recipe provides proven cases and documentation in an easy-to-understand manner that can be communicated to both leadership andthe public.

Finally, by providing examples for performance measure applications, this CV readiness recipe can help corridor managers think about how they want to monitor their corridor performance and whattype of information should be collected from the infrastructure and disseminated out to the public through dashboards, increasing the transparency of the data being collected and minimizing privacyconcerns.

5.8 Measuring Corridor Walkability

5.8.1 Section 1: Data and Overview of Procedure

This section describes a new tool suggested for development under NCHRP 08-125, aiming to make it easier to evaluate the overall pedestrian environment of a corridor.The tool awards points to a corridor segment based on a myriad of factorsthat influence pedestrian safety and attractiveness. The tool is very transparent, and the points it awards can be modified based on stakeholder opinions of relative values. The tool can be used to determine the extent to which different corridor management efforts could impact pedestrian safety and attractiveness, either positively or negatively.

Method/Tool	Corridor Management Issue Addressed
Measuring Corridor Walkability	**Problem:** Current corridor impacts measurements ignore non-motorized users and fail to account for poor pedestrian infrastructure enforces auto-dependence, thus over-burdening corridors automobile capacity with short trips and associated heavy access requirements.
	Summary of Solution: By collecting data on pedestrian infrastructure along the corridor, it becomes possible to provide a quantified metric suitable for use as a corridor performance metric. Using GIS software, it becomes possible to perform spatial analysis and represent the results in a map, providing a comprehensible representation of infrastructure and how it affects travel behavior.

5.8.2 Corridor Walkability Scoring Tool

Below is a screenshot of the new walkability scoring tool that is sensitive to many different factors that influence walkability. Select the end-state area type the community is planning for (Industrial, Suburban, Urban, Urban+), then:

- Columns B-C: Fill out the values in grey for both Baseline and Build
- Columns D-E: Value considered OK or average, vs. value considered Ideal. Negative points often issued if below OK. Zero or near-zero if OK and maximum points if Ideal.
- Columns F-G: Points awarded or removed based on the values of columns 2, 3.
- Columns H-J: Point range based on Theoretical Worst, Average Corridor, and Theoretical Best

- At both the bottom and the top are shown the positive or negative points, and then those points are normalized to a scale of 1-100, where the most unwalkable corridor imaginable would get a 1, and the most walkable imaginable would get 100.

1	A	B	C	D	E	F	G	H	I	J
2	**Bike/Pedestrian Oriented Corridor Calculator**					**-13**	**22**	**-35**	**2**	**40**
3				**Scale of 1-100**		**30**	**75**	**1**	**49**	**100**
4	Desired or Likely Future Area Type (30-yrs out)	**Urban**								
5	Corridor involves mainly two-way or mainly one-way intersections?	2						**Point Summary**		
6	**Design Attributes: Cross Section**	**Baseline**	**Build**	**Ok**	**Ideal**	**Base**	**Build**	**Worst**	**Ave**	**Best**
7	Sidewalk Quality (Scale 1-4: 1=No walk; 2=poor; 3=good; 4=great)	2	3	3	4	-3	0	-6	0	3
8	Sidewalk Width, (FT)	4	6	6	8	-2	0	-1	1	2
9	Buffer between sidewalk and curb edge (FT)	4	6	6	10	-2	0	-4	-1	2
10	Quality of sidewalk street trees (scale 1-5; 1=Worst poss, 5=Best poss)	2	5	3	4	-2	4	-3	0	4
11	Quality of sidewalk street lights (scale 1-4; 1=Worst poss, 5=Best poss)	2	4	3	4	-1	1	-1	0	1
12	Lane Width (FT)	12	10	11	10	-2	2	-2	0	2
13	Lanes: number GP lanes each direction	2	2	3	2	1	1	1	1	1
14	Bike Facilities (1=None, 2=Stripped shoulder, 3=Protected)	2	3	2	3	0	2	-1	0	2
15	Median (1=TWLTL, 2=Raised hardscape, 3=planted w/trees, 4=No Med)	1	4	2	3	-2	0	0	0	2
16	Pedestrian Refuge in Median/Cross-Walk?	Yes	Yes	No	Yes	2	2	0	0	2
17	**Design, Cross-Section Subtotal**					**-11**	**12**	**-17**	**1**	**21**
18										
19	**Design Attributes: Corridor Top View**	**Scenario**	**Scenario**	**Ok**	**Ideal**	**Points**	**Points**	**Worst**	**Ave**	**Best**
20	Driveways across sidewalks (1=Many, 2=Several, 3=Few)	1	2	3	3	-2	-1	-2	-1	0
21	Ped cross opportunity (in FT)	1000	600	660	500	1	2	0	1	2
22	If two-way intersections, select dominant type (6 options)	5	3			-1.5	3	-3	-1.5	3
23	If one-way intersections, select dominant type (8 options)	8	8			0	0	0	0	0
24	**Design, Top-View Subtotal**					**-2.5**	**4**	**-5**	**-1.5**	**5**
25										
26	**Operational Attributes: Speed, Transit**	**Scenario**	**Scenario**	**Ok**	**Ideal**	**Points**	**Points**	**Worst**	**Ave**	**Best**
27	Speed: Either posted or frequently observed (if faster than posted)	40	35	35	30	-5	-2.5	-7.5	-2.5	0
28	Transit peak period frequency (minutes - zero if no transit)	30	30	30	15	1	1	0.5	1	1.5
29	Transit: Free Fare? ("Yes" if Free or if Pass <= $50/yr; Otherwise "No")	No	No	No	Yes	0	0	2	2	0
30	Transit: dedicated lane or HOV/HOT lane?	No	No	No	Yes	0	0	0	0	2
31	**Operational Attributes: Speed, Transit: Summary of Points**					**-4**	**-1.5**	**-5**	**0.5**	**3.5**
32										
33	**Neighborhood: Parking, Network Type, Demographics**	**Scenario**	**Scenario**	**Norm**	**Ideal**	**Points**	**Points**	**Worst**	**Ave**	**Best**
34	Parking Policy (1=Significant required, 2=Not required, 3=Max allowed)	1	2	1	2	-2	0	-2	0	2
35	Network Type (1=Haphazard, 5=Tight Grid)	4	4	2	5	3	3	-1.5	1.5	4.5
36	Demographics, Leans Elderly?	Yes	Yes			2	2	-2	0	2
37	Demographics, Leans Lower-Income or young adult?	Yes	Yes			2	2	-2	0	2
38	**Neighborhood Attributes: Summary of Points**					**5**	**7**	**-7.5**	**1.5**	**10.5**
39										
40	**Normalize Scores on scale of 1-100**									
41	Raw scores before normalizing					**-12.5**	**21.5**	**-34.5**	**1.5**	**40**
42	Normalized from 1 to 100					**30**	**75**	**1**	**49**	**100**

Figure 58 Screenshot of new Corridor Walkability Tool

The Walkability Calculator is available on the National Academies Press website (nap.nationalacademies.org) by searching for *NCHRP Web-Only Document 386: Quantifying the Impacts of Corridor Management*.

5.8.3 What is Being Measured?

There are four major categories:

- **Design attributes that are cross-section oriented**, such as the width of sidewalks, buffer areas,lanes, etc.
- **Design attributes that are Top-View oriented** such as the quality of sidewalks, the scale of driveways crossing sidewalks, the distance between protected pedestrian crossing opportunities, and the nature of signalized intersections.
- **Operational attributes** such as automobile speed and status of transit
- **Neighborhood attributes** such as a community's parking policy, network type within half-mileof the corridor, and whether corridor demographics are (or will be) skewed toward elderly residents, lower-income residents, or young adults, all of whom tend to value walkable environments.

Network type and demographic attributes may be largely beyond the control of a managementteam but nonetheless affects both the overall walkability and the need for walkability.

Many of the values required as inputs are easy to discern from the spreadsheet, such as the width of travel lanes, which will typically be 10, 11, or 12-ft. Others are on a scale of 1-4 or 1-5, and still others are not really a scale, but a set of options, usually listed from worst for pedestrians to bestfor pedestrians.

5.8.4 Section 2: Outputs

Charting Results: The chart at the right is dynamically connected to the previous data. If a corridorgets 1-20 points, it is considered quite poor for walkability (dark red). Very average is 41-60 (grey). Extremely walkable would be 81-100 (dark green).

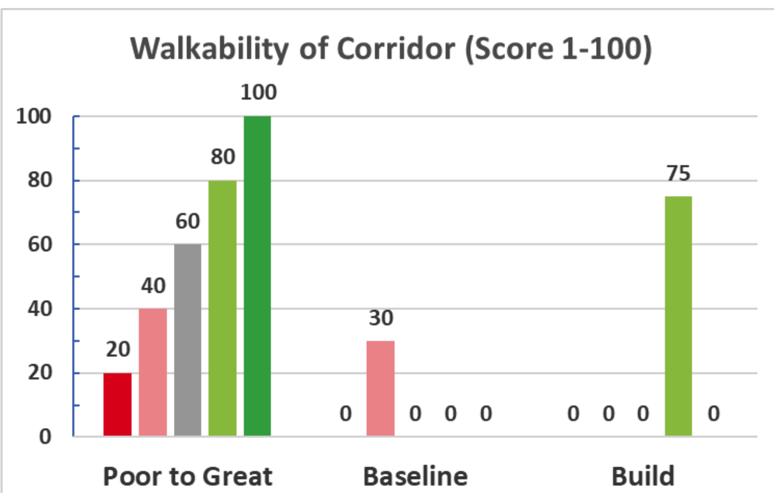


Figure 59 Results of Before/After Walkability Analysis

5.8.5 Data "ingredients" required for sketch-level analysis

Needed Input Elements

For most data requirements the ideal is to have GIS files for each. In lieu of GIS, percentage or qualitative estimates may suffice. Inputs required in include land-use attributes, right of way attributes, and pedestrian/traffic calming attributes. Detailed analysis requires detailed data on intersections characteristics.

Land-use Attributes

- Existing & desired future land-use context by corridor subarea (Industrial, Suburban, Urban,Urban Core)
- Urban and Urban Core both presume higher densities of residential and commercial in closeproximity, which will lead to higher levels of bike and pedestrian activity.
- Driveway frequency

Right-of-Way Attributes

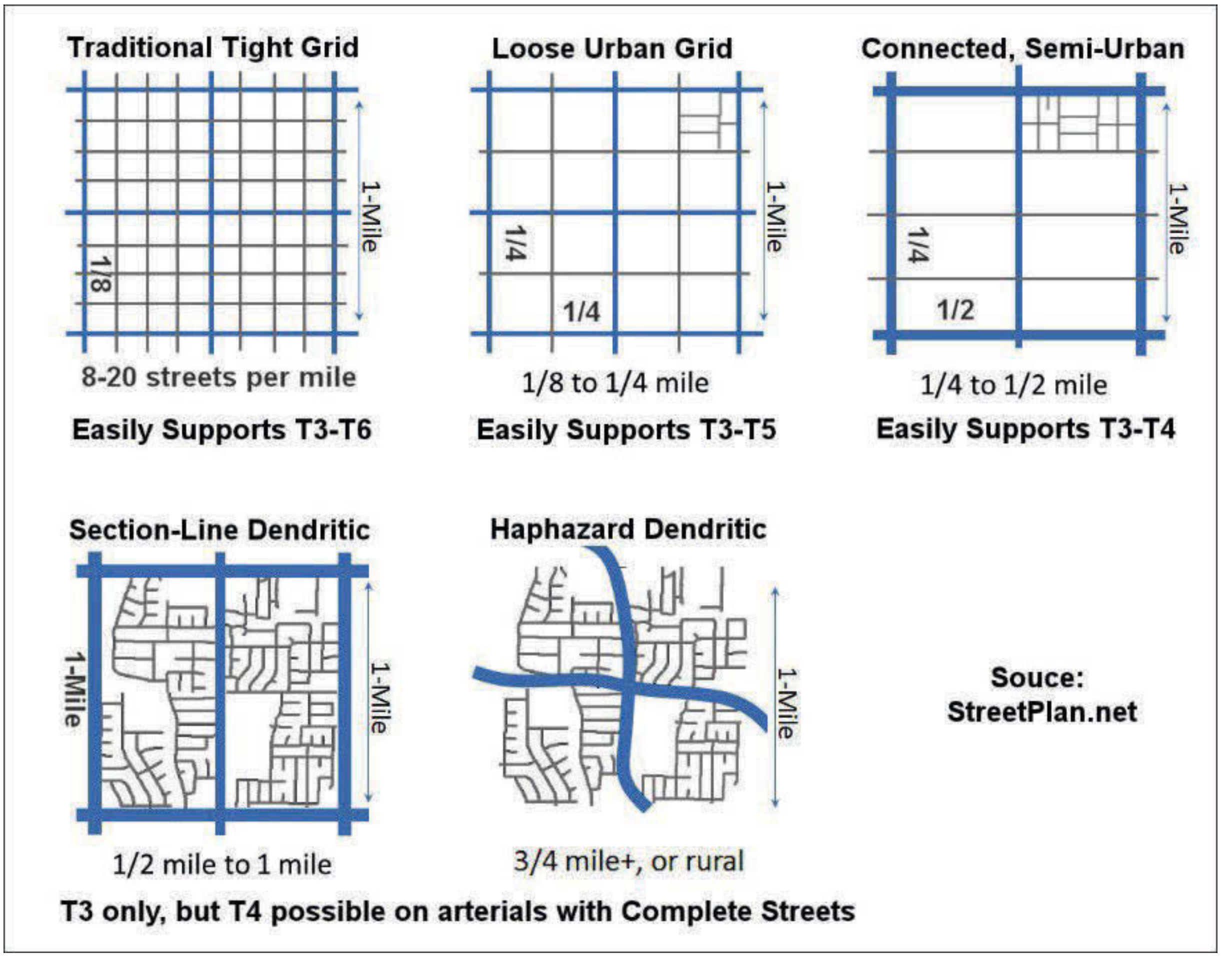
- Sidewalk presence (Estimate percent complete on each side of an arterial)
- Sidewalk width in feet (average or typical)
- Cycling: Bike lane on shoulder, cycle track above curb, pathway nearby, or nothing?
- Average buffer between sidewalk and curb edge in feet (0 to X)
- Shoulder width and typical uses
- Number of through lanes
- Divided median, raised median, or two-way turn lane (TWTL)?
- One-way or two-way arterial?
- Width of travel lanes
- Current Speed Limit
- Transit mode and frequency

Pedestrian/Traffic Calming Attributes

- Street trees/planters on roadside (scale of 1-5)
    - 1: Few trees - random and generally on private property
    - 2: Many trees, but random and generally on private property
    - 3: Some small trees, shrubs, flowers within ROW, but narrow space, poor growth.
    - 4: Many uniform trees on both sides of road, usually small.
    - 5: Many uniform trees on both sides of road, usually tall, large canopy, very healthy.
- Ped refuge in median, if two-way?
- Street Lighting Quality (scale of 1-4)
    - 1: No lighting of any sidewalk areas
    - 2: Cobra-head lights, more for autos than pedestrians
    - 3: Artistic, pedestrian-scale lighting
    - 4: Artistic, pedestrian-scale lighting, with banners and/or plant hangers

Nearby Network Attributes

- Broad Network Type, within half-mile buffer of corridor
  - Tight grid (parallel collectors or locals every 300-600 ft)
  - Loose grid (parallels every 600-1300 ft, or 1/8-1/4-mile)
  - Connected, Semi-Urban (1300-2600 ft, or 1/4-1/2-mile)
  - Section-Line Dendritic (through streets are usually 1/2-1.0-mile, generally on USGS section-lines. Streets in between wind around and often include many cul-de-sacs).
  - Haphazard Dendritic (through streets usually atleast 3/4 miles away and may be 2+ miles away).



5.8.6 More detailed analysis

Network Attributes

- Block sizes (Census blocks – smaller = more pedestrian-ready)
- Arterial Crossing Opportunity Frequency (Traffic signals, HAWK signals, crosswalks withprotected medians)

Intersection Attributes

- Two-Way or One-Way?
    - Two-way crossing two-way
    - Two-way crossing one-way
    - One-way crossing one-way
- Number of legs to intersection (3=T-intersection; 4=typical; 5+ = complex)
- Number of through-lanes on arterial of interest
- Number of through-lanes on cross-street of analysis
- Number of left-turn storage lanes at each approach
- Traditional Intersection?
    - Traditional 4-phase (NS Through, EW through, NS left-turn arrows, EW left-turnarrows)
    - Traditional 3-phase (Throughs, plus either NS or EW left-turn arrows)
    - Traditional 2-phase (Throughs only. Lefts either not permitted or must wait for gaps)
- Alternative Intersection?
    - Roundabout
    - Continuous Flow/Displaced Left Intersection
    - RCUT
    - Median U-Turn/Bowtie
    - Single Quadrant Intersection
    - Multi-Quadrant Intersection
- Number of signal phases at each signalized intersection (4, 3, 2)
    - 4-phases:
    - 3-phases: Throughs, plus either NS or EW left-turn arrows
    - 2-phases: No

5.8.7 Application Case Example

Example of Pedestrian Impact Measurement, Logan Main Street

In a project sponsored by Logan, Utah, they measured pedestrian friendliness using an ArcGIS pluginc alled "Viacity." The project situation and variables accounted for in the analysis are shown below. The methodology's application in Logan, Utah (documented in the Corridor Impact Measurement SWOT Analysis) has also since been tested in before/after studies with the new corridor walkability tool just described.

Figure 60 Logan Main Street

Main Street in Logan, Utah is unusually wide at 125 ft total right-of-way. But despite having wide sidewalks and some trees, the business community does not consider it very pedestrian-friendly largely due to a 5-lane cross-section that serves a huge 45,000 vehicles per day under extremely congested conditions. The city set goals and objectives for their MainStreet corridor that include traditional goals such as reduced traffic congestion and improved safety. But they also aim to improve the pedestrian environment and encourage even more walkable development.

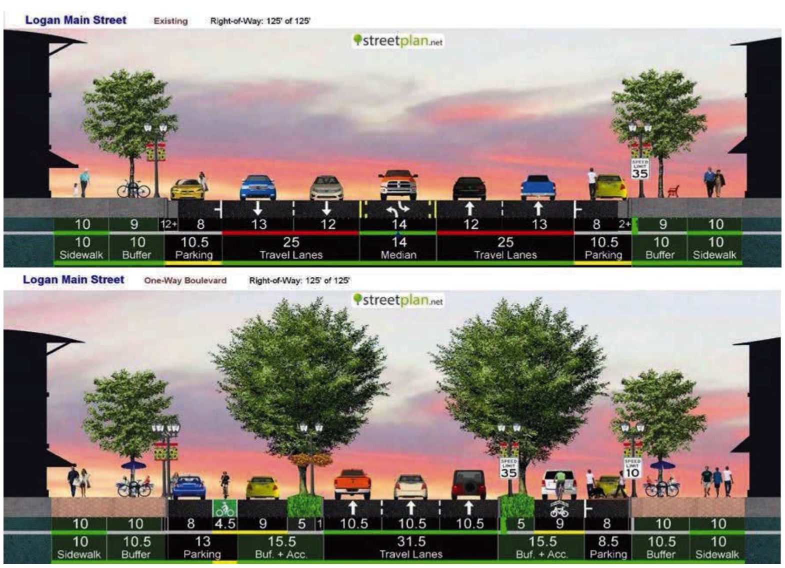


Figure 61 Logan Main Street, before and after one-way couplet

One project concept that shows high promise across all of their objectives is to convert their two-way Main Street, into a one-way couplet. Such a conversion could support higher volumes of traffic, while at the same time reducing the total number of lanes from fiveto four or even potentially three. Below compares the existing cross-section with how it might look under a one-way scenario. To understand the before and after impacts on the pedestrian environment, the city utilized an ArcGIS extension known as Viacity, and a map of that analysis is shown in Figure 62. Red parcels are where walking is deemed to be "less pleasant, less safe, and/or slow" relative to green parcels. Yellow is average. If the project is implemented as planned, the "After" diagram shows that walking on Main Street becomes entirely green or yellow with no red, so similar to most other places in the city. The change diagram shows parcels that have improved due to the project. Data that was used to create the measure included:

- Before/After signal cycle lengths (shorter cycles after = faster pedestrian cross times)
- Before/After pedestrian crash modification factors (one-way scenario is safer than atpresent due in part to fewer pedestrian conflict points, but also due to slower speedsassociated with traffic calming design)
- Before/After right-of-way allocated to pedestrians, roadside amenities, additional streettrees.
- Expectation of walk-oriented development that would occur: This was based in part on city land-use plans, but also on market analysis and stakeholder expectations of the extent to which both one-way and two-way scenarios could catalyze walkable development based onthe cross-section amenities provided by each.

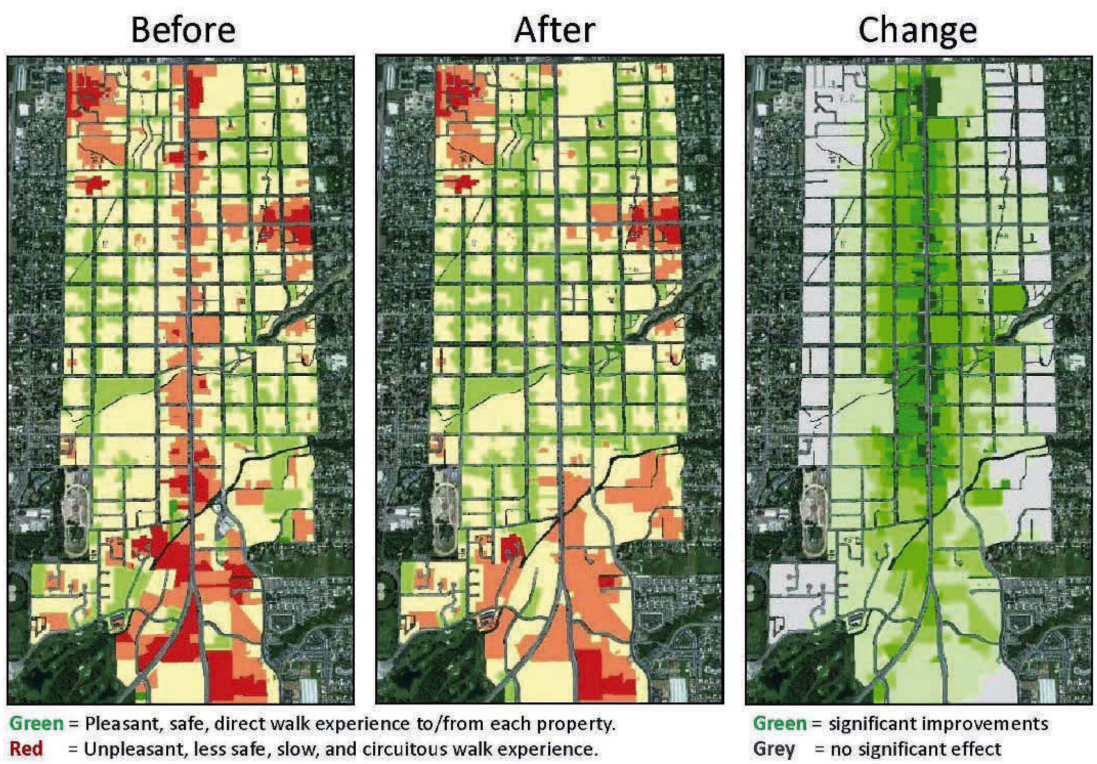


Figure 62 Before/After analysis using Viacity (Source: City of Logan Main Street Study, 2013)

This Viacity example relies heavily on routing analysis which may be hard to replicate without that plugin. So instead, the corridor was tested using the new spreadsheet tool. The two-way street has a lot going for it: walkable network, demographics, wide sidewalks and buffer area, some street trees. But it also has wide 12-ft lanes, no traffic calming median or pedestrian refuge, and high conflict points. The tool's prediction is that today's corridor is average walkability but almost good(57 of 100), while the project envisioned would create truly great walkability (91 of 100).

5.8.8 Takeaways from This Methodology

Corridor Management has traditionally focused on design and operational strategies to maximize traffic capacity and also maximize average speeds within a safety tolerance. These same objectives tend to be applied at first/last mile at-grade arterials within larger corridor systems. However, these first/last-mile arterials also tend to be where corridors touch the communities around them most directly. Auto-oriented land-uses emerged because there were significant volumes of autos. However, many communities see that land-uses along these arterials are languishing. That economic redevelopment need, along with concerns over climate change and social equity, have many communities looking to state DOTs for ways they can help reinvent these first/last mile at- grade arterials in ways that catalyze mixed-use, high-density, walkable development that can reduce VMT per capita over time, improve public health, and help them have a larger tax base fromwhich to pay for ongoing maintenance of Complete Street features.

State DOTs are very good at managing corridors to maximize speed and capacity-based performance measures but need improved methods for assessing how potential actions can influence walkability, economic development,and climate change. The Corridor Walkability Scoring Tool described here will give practitioners an easy-to-use method for evaluating the extent to which design and policy-related actions will actually create conditions that can attract patrons to alternative modes, and also catalyze development that in turn attracts patrons to those modes.

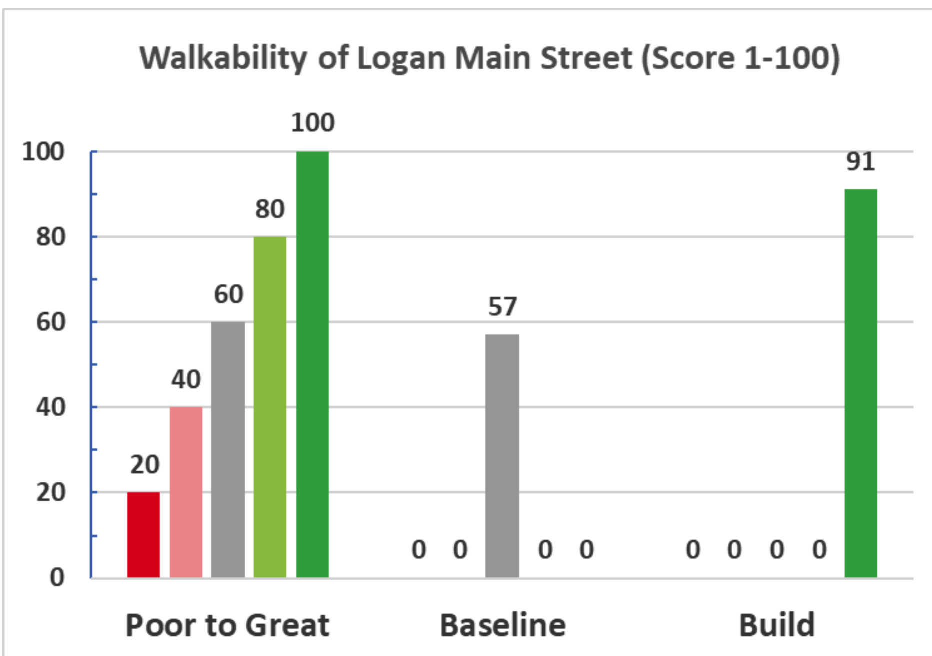


Figure 63 Results of Before/After Walkability Analysis

5.9 Testing Integrated Supply and Demand Strategies: Potential for a Generalized 7D Calculator.

5.9.1 Data and Overview of Procedure

The ability to model the marginal effects of the D-variables can be instrumental in helping corridor managers understand how the built environment affects the performance of the roadway portion of a corridor. Appendixes 10 and 11 provide an interactive calculator and supporting empirical research for quantifying specific relationships between corridor performance and the surrounding built environment. Using the basic relationships and structures provided in Appendixes 10 and 11, agencies can use statistical methods to refine this calculator, creating their own parameters when data and internal staff capabilities allow. Like the general calculator and methods in Appendix 10 and 11, 7-D calculators customized by individual agencies be used to predictexpected outcomes of changes to the built environment along a corridor. Statistical modeling of five of the seven D-variables (density, diversity, design, destination accessibility, and distance to transit) has been undertaken in the past using the University of Utah's D-variable database, the same database used previously in the built environment analysis of corridors methodology. Each study has shown clear relationships between the 5Ds and travel behaviors, although usually for specific

developments like mixed-use developments and transit-oriented developments. In particular, past research has emphasized a connection between the D-variables and VMT, although other travels behaviors could also be modeled.

The 7-D calculator provided in Appendixes 10 and 11 are based on empirical data from the University of Utah's Metropolitan Research Center, modeling travel outcomes for a sample of corridors in up to 34 regions of the United States using geocoded household travel survey data. The D-variables operationalize the constructs of density (measured as activity density), diversity (measured as land-use entropy), design of the street network (measured as intersection density and percentage of 4-way intersections), destination accessibility (measured as jobs reachable within a given travel time by automobiles and transit), and distance to transit (measured as transit stop density).

Method/Tool	Corridor Management Issue Addressed:
7D Calculator	**Problem:** Build environment effects (7D) on corridor performance insufficiently considered in practice due to lack of applicable calculations to estimate the effects of corridor characteristics on travel behavior. **Summary of Solution:** Develop a linear regression model and provide regression coefficients to enable practitioners to estimate built environment effects of corridor travel characteristics.

5.9.2 **OUTPUTS**

Data Inputs

Regression Coefficients produced using statistical analysis of the University of Utah's proprietary database of travel demand surveys and associated enriched 7D-variables.

D-variable analysis requires spatial data. Such spatial data includes TAZs with socioeconomic information, street networks, transit stops, land-use (at the parcel level), and travel times among TAZs using both automobile and transit.

Employment Data

Employment data is needed to help define a general corridor influence area, as described in the methodology below. This data is obtained from the US Census Bureau's Longitudinal Employer-Household Dynamics (LEHD) database. Specifically, LEHD Origin-Destination Employment Statistics data (LODES) are used. This dataset, which can be downloaded by state, contains employment data at the census block level. For this analysis, the location of jobs is needed, so LODES7 Workplace Area Characteristics data is used.

Census Blocks

Census blocks (in shapefile form) are also needed to help define a corridor influence area in this methodology. These can be obtained readily from the US Census

The travel outcomes modeled will include transit mode share, walk mode share, internal capture (proportion of trips that originate and terminate within the corridor segment), VMT per trip, congestion levels on the corridorsegment (delay per trip), and crash rates per VMT within the corridor segment. This will be a simple cross-sectional linear regression analysis using freeway and arterial road segments as units of analysis. This approach is similar to previous statistical modeling of theD-variables using the University of Utah's database.

Statistical modeling has never been attempted for corridors, but it has been used to model travel behaviors at the individual development and metropolitan levels. It is expected that modeling efforts will reveal useful relationships among the D-variables and travel behavior that may prove useful for corridor managers and transportation and land-use planners in their efforts to improve existing corridors and create new ones that servethe evolving goals of these major transportation facilities.

Replicating this work entails using a simple linear regression approach to model the marginal effects of changes in five D-variables. A linear regression model will be the most straightforward approach and will result in formula(e) that are most easily digestible and usable bypractitioners in the field.

Five D-variables, as mentioned previously, can be readily modeled with data in the University of Utah's database. Demand management and demographics will not be modeled because demand management typically refers to parking supply and cost (this requires in-person parkingcounts, which are not possible with the scope and budget of this project) and demographics are not a built-environment characteristic. The other five D-variables are directly related to the built environment, and the dataalready exists in one place as a result of over 10 years of data collection.

This type of analysis (and the methodology given in Appendix 11) isolate the marginal effects of D-variable changes by corridor typology (controlled-access freeways and non- controlled access metropolitan arterials) by modeling D-variable data for each separately. A separate formula can be created for at least these two corridor typologies, and any others deemed worthwhile to focus on. Separate shapefiles will be created for each corridor typology using a standardized corridor buffer area across metropolitan regions, as thisis the best way to approximate the corridor influence area on a national level. Each typology's shapefile will be used in an ArcGIS model as described in the 7D built environment analysis, and the resulting data will then be used to create a linear model by regression analysis. Expected relationships between the D-variables and each travel behavior are described in the tables below, based on previous modeling efforts with the same data.

Table 9 VMT

Dependent Variable: VMT			
Independent Variables	*Quantitative Measure*	*Hypothesized/ Expected Relationship*	*Rationale for Hypothesized Relationship*
Density	Activity density	Negative	Higher density of both jobs and residents correlates with smaller average travel distances
Design	Intersection Density	Negative	Higher concentration of intersections enables more direct routes between trip origins and destinations
Destination Accessibility	Jobs accessible within 10, 20, or 30 min by auto and 30 min by transit	Negative	The more jobs accessible within a given travel time, the less distance people must travel to get to destinations ("destinations" are typically in areas where people are employed)
Diversity	Land-use entropy	Negative	Mixed-use areas decrease travel distances because destinations are closer to residences (e.g., a householdmay be able to walk to a grocery store rather than drive)
Distance to Transit	Transit stop density	Negative	More transit stops per unit area mean transit is more accessible and attractiveas a travel mode, and every transit trip is a trip that produces zero VMT

Table 10 Transit mode share

Dependent Variable: Transit mode share			
Independent Variables	*Quantitative Measure*	*Hypothesized/ Expected Relationship*	*Rationale for Hypothesized Relationship*
Density	Activity density	Positive	Higher density areas typically experience higher transit mode share
Design	Intersection Density	Positive	Higher concentration of intersections enables transit (especially buses) to take more direct routes, and first and last-mile connections will also be more direct, making transit an attractive option
Destination Accessibility	Jobs accessible within 10, 20, or 30 min by auto and 30 min by transit	Positive	The closer a household is to jobs, the more likely they may be to take transit
Diversity	Land-use entropy	Positive	Because travel distances are shorter inmixed-use areas, transit may be more popular
Distance to Transit	Transit stop density	Positive	More transit stops per unit area means transit is more accessible and attractive as a travel mode

Table 11 Walk mode share

Dependent Variable: Walk mode share			
Independent Variables	*Quantitative Measure*	*Hypothesized /Expected Relationship*	*Rationale for Hypothesized Relationship*
Density	Activity density	Positive	Higher densities encourage walking because origins and destinations are closer together
Design	Intersection Density	Positive	Higher concentration of intersections means people walking can take, shorter more direct routes
Destination Accessibility	Jobs accessible within 10, 20, or 30 min by auto and 30 min by transit	Positive	The more jobs close to a household, themore likely they are to walk to their destination
Diversity	Land-use entropy	Positive	Most previous research indicates that mixed-use areas encourage walking because origins and destinations are closer to each other
Distance to Transit	Transit stop density	Positive	Every transit trip is a walking trip, so higher availability of transit will naturally, encourage more walk trips.

Table 12 Internal Capture

Dependent Variable: Internal Capture			
Independent Variables	*Quantitative Measure*	*Hypothesized/ Expected Relationship*	*Rationale for Hypothesized Relationship*
Density	Activity density	Positive	Higher density areas may often be mixed-use areas in which people may not have to travel outside the area for some trips.
Design	Intersection Density	Positive	Availability of direct routes within a corridor area may encourage people to stay within the corridor area for trips
Destination Accessibility	Jobs accessible within 10, 20, or 30 min by auto and 30 min by transit	Positive	Closer availability of jobs may mean more jobs are within the corridor, thus increasing internal capture
Diversity	Land-use entropy	Positive	If a corridor area is mixed-use, trips are more likely to start and end within it compared to a mostly single-use corridor
Distance to Transit	Transit stop density	Positive	Higher availability of transit will typically correlate with denser, morediverse areas, which will mean more trips staying within the corridor area.

Table 13 Congestion

Dependent Variable: Congestion			
Independent Variables	*Quantitative Measure*	*Hypothesized /Expected Relationship*	*Rationale for Hypothesized Relationship*
Density	Activity density	Positive	Higher density areas are likely to experience more congestion due to a high concentration of residents and jobs
Design	Intersection Density	Negative	Higher intersection density areas have more opportunities to take alternate routes to avoid traffic, which would decrease congestion
Destination Accessibility	Jobs accessible within 10, 20, or 30 min by auto and 30 min by transit	Positive	Areas with high destination accessibility are typically more dense, meaning they will likely have higher congestion
Diversity	Land-use entropy	Negative	Higher land-use diversity will encourage use of more efficient modes like transit, walking, and bicycling, which would resultin lower congestion
Distance to Transit	Transit stop density	Negative	Higher transit stop density will encourage people to use transit more, which will result in lower congestion.

Table 14 Crash Rates

Dependent Variable: Crash Rates			
Independent Variables	*Quantitative Measure*	*Hypothesized/ Expected Relationship*	*Rationale for Hypothesized Relationship*
Density	Activity density	Negative	Driving speeds tend to be lower in high-density areas, which may decrease crash rates
Design	Intersection Density	Negative	Dense street networks typically exhibit lower crash rates due to lower speeds reached between intersections
Destination Accessibility	Jobs accessible within 10, 20, or 30 min by auto and 30 min by transit	Negative	High destination accessibility may limit crash rates because people will spend less time driving to get places
Diversity	Land-use entropy	Negative	People will drive less in mixed-use areas, meaning higher diversity correlates with lower crash rates
Distance to Transit	Transit stop density	Negative	Higher transit availability will encourage people to take transit more frequently, thus reducing the number of cars on the road that could potentially be involved in a collision

5.9.3 Expected Use in Final Research Products

Any statistical models produced as a result of this modeling approach could be easily used to createa widely applicable formula for use by practitioners. This formula could be used in something as simple as an Excel spreadsheet to predict expected travel behaviors in any corridor segment of the matching typology. Provided practitioners have the proper data to calculate the D-variables on their own, they could simply plug the values into the equation and come up with probable outcomes for different corridor management scenarios or simply produce a descriptive picture of the existing corridor. Planners, in particular, could use the formula(e) in scenario planning exercises when planning to construct new corridors or reconstruct existing ones.

The model(s) produced will be largely in line with traditional corridor management goals of reducing congestion and maximizing safety on corridors, corridor managers aim to understand therelationships between the D-variables and these outcomes. The model(s) produced in this approach will also enable corridor managers and planners to consider outcomes outside of the traditional corridor management approach, such as VMT and mode share. As the transportation planning profession evolves, there will very likely be more pressure on practitioners to focus on alternative performance measures such as sustainability and livability. Reducing VMT and increasing transit and walk mode shares will be increasingly important performance measures as the transportation planning paradigm continues to shift away from auto-mobility. These new models will enable an analysis of corridors that will be very relevant well into the future.

Determining the marginal effects of changes in the D-variables using statistical modeling is the ultimate use of the D-variables, as without a solid model they are merely descriptive data points. Based on the literature cited in Appendix 1, the D-variables can be modeled for corridors, it will be much easier for practitioners to integrate them into their management and planning processes for corridors. Statistical modeling may not be something that some corridor managers and planners are able to do for the D-variables for various reasons, so producing formulae that can be widely used will be an extremely helpful tool.

Practitioners who are able to carry out statistical modeling can also save time if a model is readily available for them to use. As such, this approach could be an extremely valuable element for implementing the Playbook.

5.10 Corridor and Network Capacity Methodologies and Calculators

Corridor Management often includes strategies and technologies to improve the efficiency of existing vehicle lanes, and also can include alternative modes for increasing the person-trip throughput of corridors. Corridors are also affected by the nature of the background support network. This is a short overview of the NCHRP 08-124 effort which created new methodologies for evaluating corridor and network-level analysis and a description of the accompanying Excel-based calculators.

5.10.1 Freeway Corridor Person-Trip Calculator

Urban freeway corridors often have many features that influence the overall ability to move people and goods. Below are more common (green) and less common or emerging (blue):

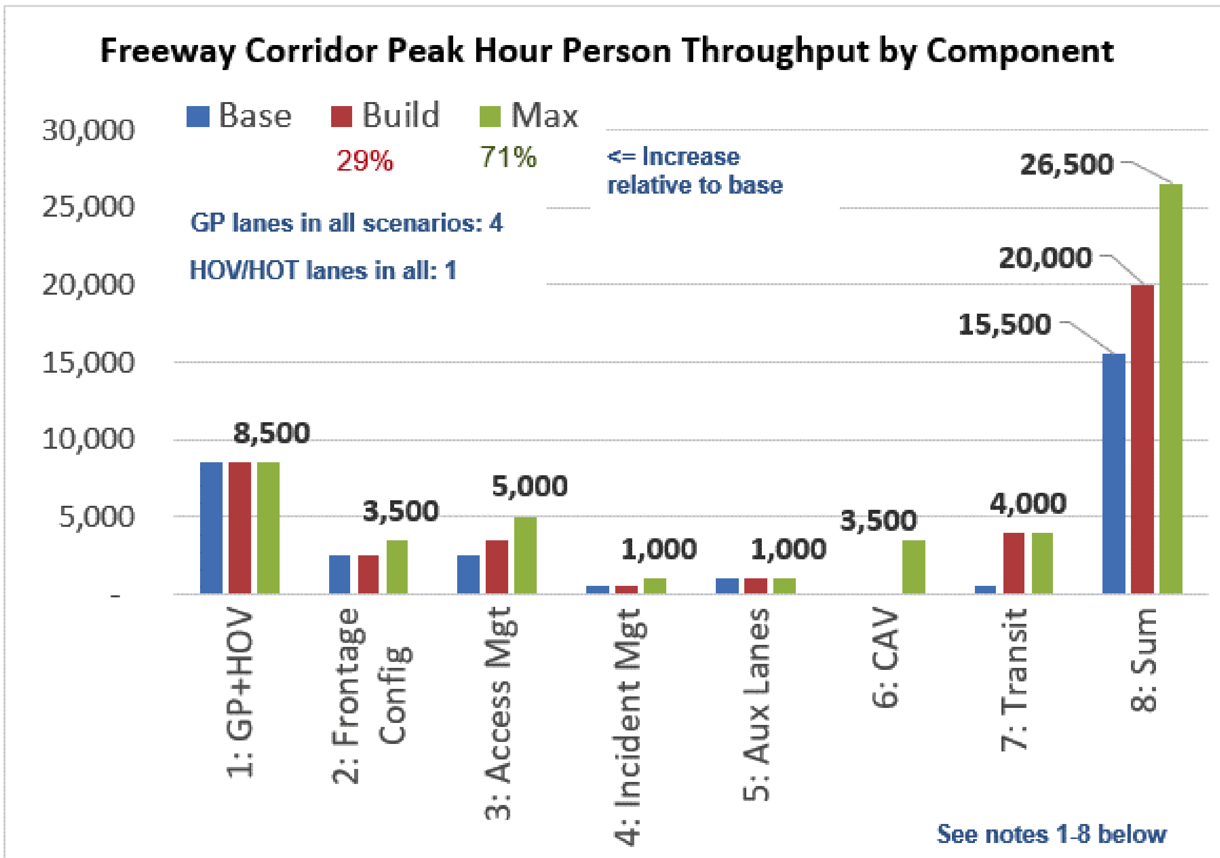
- General-purpose lanes & HOV/HOT lanes
- Auxiliary lanes (for on-ramp/off-ramp weaving)
- Ramp Metering methods and policies
- Congestion Pricing (preventing stop-n-go)
- Frontage roads (one-way or two-way)
- Incident Management Equipment & Policies
- Alternative mode options and associated fares
- Connected and Autonomous Vehicle (CAV)

An Excel calculator (see below) was created to help you determine the overall person-trip capability of a freeway corridor as it stands today, compared to a Build scenario likely to offer higher throughput potential given the same number of overall freeway lanes. In many cases such as ramp metering or congestion pricing, "Build" may not require much actual infrastructure, but instead, require a commitment to manage the system for maximum efficiency. The "Max" scenario represents the maximum or most efficient, form of the option (which may be politically difficult). Max is used to define 100 on a scale of 1-100, so the user can then see how a base and build compare to this perfect-score scenario. Grey cells are where the user makes changes. The right side of the table tabulates points toward both functional and environmental sustainability.

	Base	Build	Max	Base	Build	Max	Base	Build	Max
Step 1: Basic attributes of the freeway corridor									
Base Auto Occupancy	1.4	1.4	1.4	F.Sust.	F.Sust.	F.Sust.	E.Sust.	E.Sust.	E.Sust.
General purpose lanes, each dir	4	4	4	0	0	0	-1	-1	-1
HOV/HOT Lanes, each dir	1	1	1	1	1	1	1	1	1
HOV Min Occupancy	2	3	4+	0	1	2	0	1	2
Full-length Aux Lane?	Yes	Yes	Yes	1	1	1	0	0	0
Frontage Road Configuration	Two-way, both sides	Two-way, both sides	One-way both sides	0	0	2	0	0	2
Step 2: Base-case and build policies designed to reduce likelihood of overloading freeway									
Ramp Metering Method	No Metering	Traditional, Uncoordinated	Coordinated, Algorithmic	0	1	3	0	0	0
Ramp Metering Policy	No Meters	Up to 4-min	6+, if nec.	0	1	3	0	0	0
Congestion Pricing?	None	Full Fwy, limit $max	Full Fwy, no $Limit	0	3	6	0	3	6
Incident management policy	No program or policy	Arrive Quick, Remove Slow	All Fast: Push, Pull, or Drag	0	1	2	0	0	0
Step 3: Base and build transit situation, and any assumptions about future Connected and Autonomous Vehicle efficiency gains									
Transit, Long Distance	Express Buses	Two transit options	Two transit options	1	4	4	1	4	4
Peak Hour Screenline Ridership	600	1800	1800						
Free/Low Fare Transit?	No	Yes	Yes	0	2	2	0	2	2
CAV Throughput gains (1.0 if no CAV)	1.00	1.00	1.30	0	0	2	0	0	0
			Points, Raw	3	15	28	1	10	16
			Points, 1-100	11	54	100	6	63	100

Access: The Corridor and Network Multimodal Capacity Calculators are available on the National Academies Press website (nap.nationalacademies.org) by searching for *NCHRP Web-Only Document 386: Quantifying the Impacts of Corridor Management.*

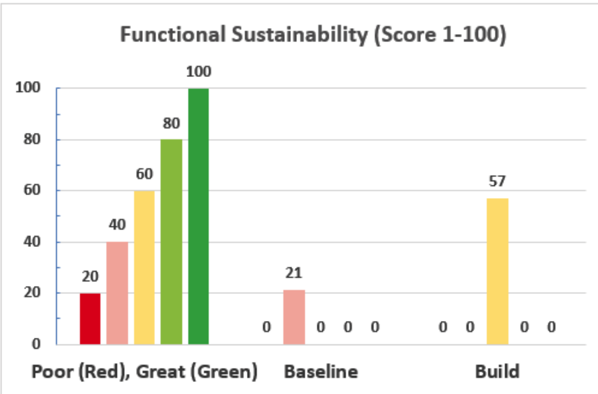
This graphic shows the various components of the corridor's peak hour person-trip throughput. This case evaluates a 10-lane freeway (four general-purpose lanes + 1 HOV/HOT lane, in each direction). Notice in the base case that these lanes contribute about 8,500 person-trips per hour, but the overall corridor can carry 15,500 trips per hour. The additional trips are accomplished using two-way frontage roads, traditional ramp metering (access mgt), typical incident management, auxiliary lanes, and a modest amount of transit.

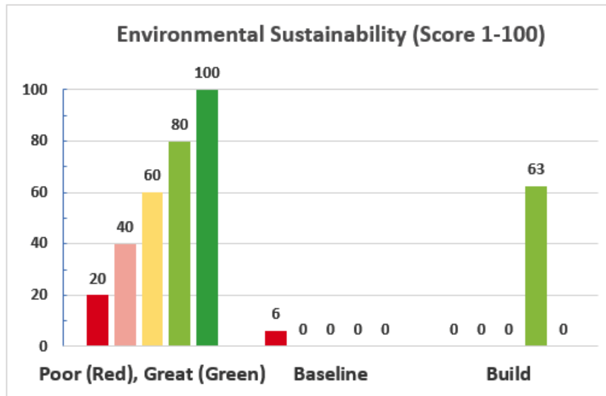


However, there is much more potential for higher person-trip throughput even with the same number of lanes. For example, reconfiguring frontage roads from 2-way to 1-way will boost overall throughput. Modern algorithmic ramp metering and congestion pricing can eliminate stop-n-go, keeping throughput as high as possible. A "push, pull, or drag" policy can minimize the impacts of incidents. More attractive forms of transit, or free/low-fare transit, can attract many more riders (freeing up space in vehicle lanes). Down the road, CAV has the potential to increase lane capacity. In this case, the potential throughput is 26,500 people per hour – 71% higher than today's 15,500. Prioritizing management strategies over more expensive construction strategies can be a good way to make the most of what you have.

5.10.2 Sustainability Scores

In addition to computing throughput estimates, the tool rates a user's baseline and build scenarios on a scale of 1-100 for functional and environmental sustainability. Anything under 20 is a poor performer relative to its potential, and anything over 80 is getting about all that it could likely get. In this case, the baseline is poor in both forms of sustainability, while the proposed projects and policies for Build make it far more sustainable.

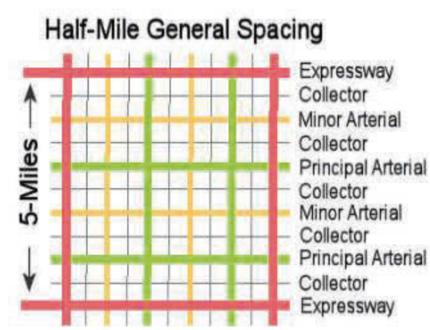




About Sustainability Scores: These charts show how well your base case and build scenarios are performing relative to the Max scenario. Max is by definition 100 points, assuming it were possible to do all things in the corridor that would secure maximum functional and environmental sustainability.

5.10.3 Regional and Study Area Network Analysis

NCHRP Report 917, the Right-sizing Guidebook, features a recommendation first proposed by the Institute of Transportation Engineers that fully developed suburban/urban areas would do well to have an expressway every 5-miles, arterial every 1-mile, and a collector every half-mile. This diagram depicts a "fishnet grid" tile that matches this recommendation.



NCHRP 08-124 recognized that this 5x5 "tile" may be more network than is needed at buildout for locations with wetlands, mountains, or large swaths of large-lot suburbs, and developed patterns for 7x7 and 10x10 tiles as shown below.

Fishnet pattern for 5x5-mile tile, where buildout has little open space and is likely to be heavily suburban, with a fair amount of urban.

Miles from Expwy 1	-	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
Roadway ID	1	2	3	4	5	6	7	8	9	10	Rpt	2	3
Functional Class	E	C	M	C	P	C	M	C	P	C	E	C	...

Expressway/Fwy	Minor Arterial
Principal Arterial	Collector

Fishnet pattern for 7x7-mile tile, where buildout includes significant open space or a great many large-lot neighborhoods

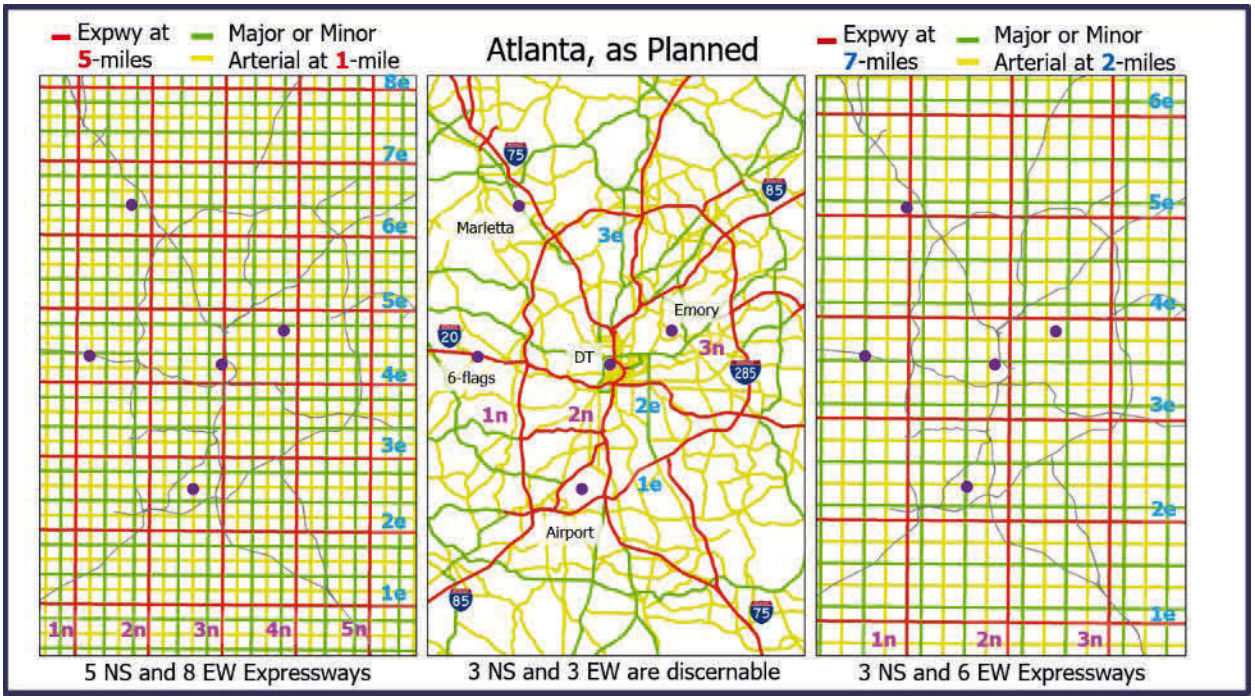
Miles from Expwy 1	-	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0
Roadway ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Rpt	2	3
Functional Class	E	C	P	C	C	M	C	C	P	C	C	M	C	C	E	C	...

Rpt Repeat Pattern

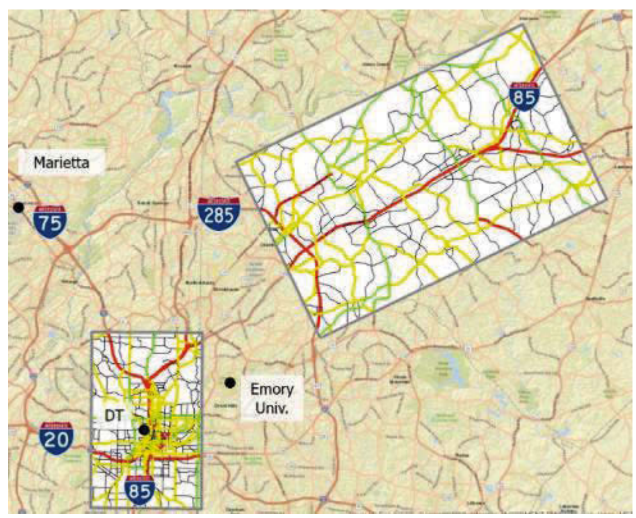
Fishnet pattern for 10x10-mile tile, where buildout includes significant open space or low density (Made for Asheville area)

Miles from Expwy 1	-	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0
Roadway ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Rpt	2	3
Functional Class	E	C	C	M	C	C	P	C	C	M	C	C	P	C	C	M	C	C	P	C	E	C	...

In this graphic, Atlanta is compared to both the 5x5 tiles and 7x7 tiles. In both cases, the existing network appears to be lacking both expressway and arterial corridors. This may be a significant reason why the corridors that do exist are so overwhelmed – there simply aren't enough of them relative to the population that has emerged.



The spreadsheet tool offers analytical means of evaluating both regional and study-area networks to determine adequacy. In the graphic adjacent there are two study areas: the downtown area, and also the I-85 corridor northeast of downtown.



The next pages show some graphics and calculations, primarily from GIS analysis, that relied on tables in the spreadsheet tool.

Intersections	SqMi	147.0	
	I-85 North		
	Bench	Actual	Pct
Exp X Exp	6	2	33%
Exp X Art	20	10	50%
Art X Art	60	35	58%
Collectors	160	80	50%
Total	246	127	52%

Intersections per Sq Mi.	I-85 North		
	Bench	Actual	Pct
Exp X Exp	0.0	0.0	33%
Exp X Art	0.1	0.1	50%
Art X Art	0.4	0.2	58%
Collectors	1.1	0.5	50%
Total	1.7	0.9	52%

Above is a comparison of how many intersections a highly connected, highly resilient network would have relative to how many it actually has. Actual is only 52% of ideal.

In this visual comparison (left), it is easy to see the over-reliance on just a few corridors. A GIS analysis shows that while actual has fewer miles of expressways than the fishnet grid, the lane miles are higher than in the fishnet. Using tables in this spreadsheet, total peak hour VMT capability was computed for the fishnet grid and the actual network. Actual expressways have 20% more VMT capability, while everything else has less capability. While the network itself is sparse, overall VMT capability is 95% of what the fishnet grid can support. This suggests that any given road is likely far larger than it would have been in the fishnet scenario, and freeways, in particular, have been super-sized over time, in large part because they are serving local circulation due to an overwhelmed background network.

Lane Miles	SqMi	147.0	
	I-85 North		
	Bench	Actual	Pct
Expressway	264	378	143%
Principal	595	417	70%
Minor	476	251	53%
Collector	614	478	78%
Total	1949	1525	78%

VMT Capability	SqMi	147.0	
	I-85 North		
	Bench	Actual	Pct
Expressway	1,000,000	1,200,000	120%
Principal	500,000	400,000	80%
Minor	400,000	300,000	75%
Collector	200,000	100,000	50%
Total	2,100,000	2,000,000	95%

How does this help corridor management?

Understanding the larger context can help reveal why critical corridors are under pressure. An under-sized background network can lead the user to look outside the immediate corridor for opportunities to enhance connectivity. In rural areas quickly transitioning to suburban, it helps reveal opportunities to work with locals to preserve an adequate background network so that critical corridors never become overwhelmed.

5.11 Technology Readiness & Utilization Report Card

This section is a self-assessment to evaluate technology readiness along a corridor and to determinewhere a corridor is in its technology journey. It should be noted that this assessment is intended for arterial corridors with traffic signals; however, it can be applied to an unsignaled corridor, especially if there are roadside units collecting and dispersing traffic information. This assessment can be completed on an annual basis to determine the progress of a corridor and help outline a strategy for the following year. Answer the questions to the best of your knowledge. At the end of the assessment, review the points for each of your answers for a final score and associated information.

1. Does the corridor have traffic signals?

☐ A. Yes

☐ B. No

A smart corridor is not required to contain traffic signals, but having this infrastructure usuallyallows for easier integration of connected vehicle (CV) technology.

2. Does the corridor have roadside units/sensors?

☐ A. Yes

☐ B. No

☐ C. I don't know

Roadside units or sensors can be used for non-signalized corridors. They can be embedded into the pavement or mounted on a pole or other fixtures. They can monitor and provide CV with real-time information such as road conditions, traffic, speeds, accidents, emergency vehicles, weather, etc.

They can also communicate with one another through inductive loop detectors, radar, infrared,ultrasonic, and magnetometers.[6]

3. Are there any communication capabilities along the corridor, such as fiber or cellular?

☐ A. Yes

☐ B. No

☐ C. I don't know

This communication network allows for infrastructure along the corridor to report real time data back to a Traffic Management Center (TMC) or data center. Engineers and technicians can use this data to identify operation or maintenance issues as well as make on-the-fly adjustments to signal timing and phasing.

4. How do the signals or roadside units communicate operating information to a trafficmanagement center (TMC), data center, or transportation department?

☐ A. Fiber

☐ B. Cellular

☐ C. There is no communication, we monitor based on physical visits or calls from drivers

☐ D. I don't know

There are two main communication methods for data to relay back to a TMC or data center –underground fiber optics and cellular routers that are installed on the traffic poles.

5. If there is communication with a TMC, is a system in place for the TMC to remotely adjustand troubleshoot issues?

☐ A. Yes, a TMC receives data from signals and can adjust remotely

☐ B. No, the signals do not communicate with a TMC

☐ C. I don't know

In Georgia, for example, GDOT uses MaxTime software that collects signal information, which is transferred to the ATMS (MaxView), which allows engineers and technicians to remotely access thesignals.

6. Are the signal hardware (e.g., signal cabinet) or roadside unit hardware and softwareoutdated?

☐ A. Yes

☐ B. No

☐ C. I don't know

Some hardware cannot support newer software technologies, such as advanced traffic management systems (ATMS) and CV applications. Older traffic cabinets are likely to need replacement before this technology can be applied.

7. Do you actively manage timing and synchronization through an advanced traffic management system (ATMS)?

☐ A. Yes

☐ B. No

☐ C. I don't know

There are many ATMS software available that collect real-time traffic data through sensors, push buttons, radar, and lidar. This information is collected and transmitted back to a TMC or data center to post-process into ongoing monitoring and performance measures. In many cases, engineers and technicians will receive alerts if any part of the signal system goes offline or requires maintenance. They can also adjust the signal settings remotely, reducing the need for physical visits to the signal.

8. Do you have the capability to broadcast signal phasing and timing (SPaT) information either through Dedicated Short-Range Communication (DSRC) radios, Cellular, or Satellite?

☐ A. Yes

☐ B. No

☐ C. I don't know

Broadcasting traffic signal information to CVs can be achieved through three methods – DSRC, Cellular, and Satellite. Most systems use DSRC and Cellular as they can operate within the Federal Communication Commission (FCC) "safety spectrum," which is dedicated to transportation and CV telecommunication. Satellite can be used as a backup communication if either the DSRC or Cellular loses connection but is not recommended for time-sensitive information, such as signal phases andtiming, since the information is delayed before it is received by the vehicle.

9. Have you established a standard for broadcasting traffic signal or roadside sensorinformation?

☐ A. Yes, our standard is DSRC

☐ B. Yes, our standard is 4G Cellular

☐ C. Yes, our standard is satellite

☐ D. Yes, our standard is both DSRC and 4G Cellular

☐ E. No, we are waiting for 5G

☐ F. No, we have no plans to establish a standard

☐ G. I don't know

It is important for a department of transportation or jurisdiction to determine a communication standard for interoperability. While both DSRC and Cellular radios can be installed at a single location, they cannot be used at the same time. It is undetermined which radio on-board units (OBU) vehicle manufacturers will install.

10. Have you applied any applications for signal pre-emption or signal priority?

☐ A. Yes

☐ B. No

☐ C. I don't know

Signal priority uses an onboard unit (OBU) on a vehicle to notify a signal the vehicle is approaching.The signal will extend green light phases until the vehicle crosses the intersection. If the signal is red, it can reduce the green light phase for the other direction to allow the vehicle to continue moving without slowing down or stopping. Signal pre-emption is similar in that it detects the emergency vehicle approaching and turns all other directions red allowing the vehicle to cross the intersection safely.

11. Have you installed CV Adaptive Signal Traffic Control (ASTC)?

☐ A. Yes

☐ B. No

☐ C. I don't know

CV-based ASTC systems can provide real-time spatial information (such as position, speed, and acceleration, and other traffic data) necessary for evaluating traffic conditions on a road network. Communications between a vehicle and infrastructure enable the intersection controller to obtainmuch more detailed information of the surrounding vehicle states within the transmission range.

12. Do you provide any electric vehicle charging stations along the corridor? (This can includestations just off the corridor)

☐ A. Yes

☐ B. No

☐ C. I don't know

Electric vehicles are continuing to gain popularity, especially in urban areas. Charging stations can be stand-alone in parking lots but can also be implemented in streetlights for on-street parking.

13. When was the last time the pavement markings were re-painted?

☐ A. 0-2 years

☐ B. 3-5 years

☐ C. 6-10 years

☐ D. 10 years+

Autonomous (driverless) vehicles use a variety of sensors, radar, and lidar to visualize and detect objects in the roadway. These include lane assist and can "see" the pavement markings. The newer the paint or thermoplastic paint, the greater the reliability of the vehicle sensors.

14. Does the corridor have any midblock pedestrian crossings or unsignaled intersections where flashing beacons have been installed to notify drivers of pedestrians?

☐ A. Yes

☐ B. No

☐ C. I don't know

Flashing pedestrian beacons are a safety feature for pedestrians crossing the road at mid-block crossings between signalized intersections or at unsignaled intersections. They can range from flashing yellow lights to notify drivers to be cautious, or they can require drivers to stop at the crossing to allow for pedestrians to safely cross the road. For wider roads, pedestrian refuge areas may be installed to allow for a safe space for pedestrians between the two traffic directions.

15. If there are bicycles along the corridor, do you provide bicycle traffic signals?

☐ A. Yes

☐ B. No

☐ C. I don't know

☐ D. Bicycles are not allowed on this corridor

If bicycle lanes are provided, signals can be installed that detect the bike approaching and can induce a red light for vehicles to allow the bicycle to cross safely. They are not given priority but introduce another phase at the signal.

16. **Have you implemented smart streetlights that adjust lighting based on activity and collectreal-time information?**

☐ A. Yes

☐ B. No

☐ C. I don't know

Smart streetlights can include several features. Many adjust lighting brightness depending on time of day or the activity it detects through sensors. Other sensors can also be installed in the poll, including gunshot detection, cameras, weather sensors, roadside units, etc.

17. **If you have parking along the corridor, have you implemented a parking availability/parking meter application?**

☐ A. Yes

☐ B. No

☐ C. This corridor does not have parking

☐ D. I don't know

In congested areas, parking availability applications notify drivers of spaces that are empty and available in the area. This reduces congestion and increases safety as drivers are searching for parking. Additionally, smart parking meters allow for drivers to book and pay for parking through a mobile application, reducing the need for additional parking infrastructure and physical enforcement.

18. **If your corridor has curb space that includes parking, have you implemented any dynamicmessage signs to create a flexible curbside to permit specific uses during specific times of the day?**

☐ A. Yes

☐ B. No

☐ C. This corridor does not have on-street (curb) parking

☐ D. I don't know

Flexible curb space is a relatively new idea for congested corridors. With the increase in e- commerce and transportation network companies (e.g., Uber, Lyft), curb space is at a premium. Corridor management can include dynamic signs to allow for certain curb uses during time of day or based on demand. They can be used in conjunction with roadside sensors to detect parked vehicles, as well as cameras for curb enforcement.

19. **Have you installed any enforcement technologies, such as cameras or license platereaders, for crime prevention or parking enforcement?**

☐ A. Yes

☐ B. No

☐ C. I don't know

Cameras can be used to monitor accidents and criminal activities in addition to traffic operations. These video systems can be connected directly to police departments if desired, where officers can access cameras from mobile devices. License plate readers can be used for several applications including monitoring parking and identifying vehicles that have been associated with crimes.

20. Is any technology being used to route trucks along the corridor?

☐ A. Yes

☐ B. No

☐ C. I don't know

A variety of tools and applications exist for truck routing. Many use in-cab mobile applications toalert drivers with routing and other information. Data sharing partnerships may be needed to provide parking information for public facilities such as rest areas.

21. Is any technology being used to disseminate truck parking availability?

☐ A. Yes

☐ B. No

☐ C. I don't know

Truck parking along corridors is a growing need nationwide, particularly along freight corridors. Technology solutions may include vehicle-detection systems that calculate available parking spaces, data sharing to a 3rd party processor or public API, and delivery information via roadway signs, websites, and navigation systems. The Truck Parking Information Management System along the I- 94 corridor is an example. Examples of applications the disseminate parking availability informationto drivers include TruckSmart, Park My Truck, New Jersey Transportation Planning Authority, Trucker Path, Road Breakers, and Drivewyze. Websites like Trucks Park Here and state 511 websitesoffer similar information.

22. If data is collected on the corridor, are any data-sharing partnerships or open dataplatforms in place?

☐ A. Yes

☐ B. No

☐ C. I don't know

Data sharing partnerships can occur among DOTs, local and regional jurisdictions, corridor coalitions, and private sector entities like mobile application developers. Such data-sharing partnerships reduce cost burden, and data can be used for performance monitoring, open datadashboards, and application development.

23. Do the local jurisdictions along the corridor have communication and technology in place, such as internet and cellular coverage?

☐ A. Yes, the surrounding jurisdictions have sufficient internet and cellular coverage

☐ B. No

☐ C. I don't know

It is also important to note that corridors that traverse multiple jurisdictions may span across areasthat vary in terms of technology and communication coverage. Additionally, the corridor right-of-way and area serving the corridor can function as part of a larger smart corridor system beyond theroadway itself.

SCORES:

1.) A = 1, B = 0
2.) A = 1, B = 0, C = 0
3.) A=1, B=0, C=0
4.) A = 1, B = 1, C = 0, D = 0
5.) A = 0, B = 1, C = 0
6.) A = 1, B = 0, C = 0
7.) A = 1, B = 0, C = 0
8.) A = 1, B = 1, C = 1, D = 2, E = 0, F = 0, G = 0
9.) A = 1, B = 0, C = 0
10.) A = 1, B = 0, C = 0
11.) A = 1, B = 0, C = 0
12.) A = 3, B = 2, C = 1, D = 0
13.) A = 1, B = 0, C = 0
14.) A = 2, B = 0, C = 0, D = 1
15.) A = 1, B = 0, C = 0
16.) A = 2, B = 0, C = 1, D = 0
17.) A = 1, B = 0, C = 0
18.) A = 1, B = 0, C = 0
19.) A = 1, B=0, C=0
20.) A = 1, B=0, C=0
21.) A = 1, B=0, C=0
22.) A = 1, B=0, C=0
23.) A = 1, B=0, C=0

LESS THAN 10: LOW TECH

YOU ARE AT THE BEGINNING OF THE JOURNEY WITH LOTS OF OPPORTUNITY IN FRONT OF YOU! IF YOU ANSWERED "I DON'T KNOW" TO MORE THAN THREE QUESTIONS, YOU SHOULD BEGIN BY COORDINATING WITH THOSE WHO WORK CLOSELY ON THE CORRIDOR,SUCH AS TRAFFIC OEPRATIONS AND PUBLIC WORKS. YOU SHOULD FIRST FOCUS ON THE BASICS FOR THE CORRIDOR INCLUDING COMMUNICATION CAPABILITY BETWEEN SIGNALSAND MANAGEMENT CENTERS. IF YOU HAVE THAT, THEN THINK ABOUT TRAFFIC MANAGEMENT SOFTWARE AND BROADCASTING CAPABILITIES.

BETWEEN 5-19: MODERATE TECH

YOUR ADVENTURE HAS BEGUN! CONTINUE MAINTAINING THE TECHNOLOGY ALREADY INSTALLED AND BEGIN THINKING ABOUT OTHER TECHNOLOGY FEATURES OR AMMENITIESTHAT MAY BENEFIT THE CORRIDOR. PAY ATTENTION TO QUESTIONS YOU ANSWERED NO AND EXPLORE THOSE OPPORTUNITIES.

ABOVE 19: HIGH TECH

YOU ARE TECHNOLOGY SAVVY! IT TAKES TIME AND DEDICATION TO OUTFIT A CORRIDOR WITH THIS TECHNOLOGY AND YOU HAVE ACCOMPLISHED MAJOR GOALS. CONTINUE THE GREAT WORK AND SHARE YOUR SUCCESS SO OTHERS CAN LEARN FROM YOU!

Appendix 6

Methods for the Corridor Orientation Tool

The Corridor Orientation Tool used with the Playbook is rooted ina cohesive and replicable corridor impact methodology, which has been tested collaboratively with transportation agencies in the winter and early spring of 2021.

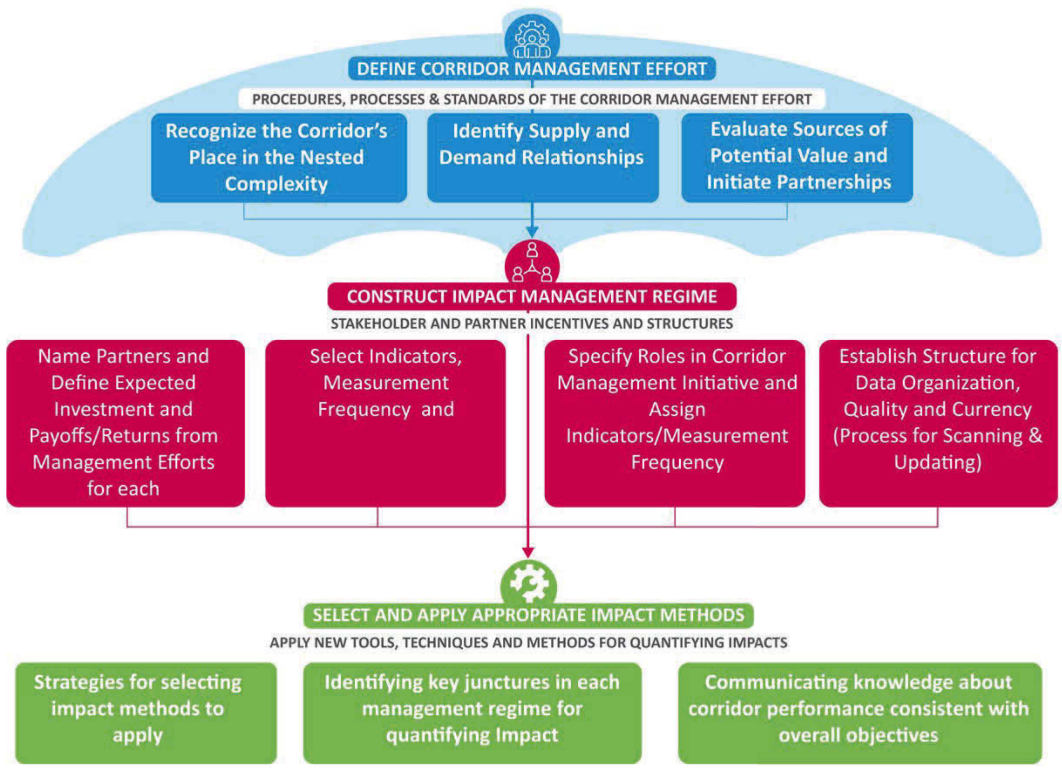
The literature review and case research (Appendixes 1 and 3), as well as the observations in the corridor innovation database (Appendix 9), make it clear that given the diversity of corridor management contexts, it is unlikely that there will be a singular one size fits all spreadsheet, GIS layout, or other tool that can be universally applied to all corridors in all contexts to compute a set of impacts appropriate for all settings. The Playbook is constructed in response to agencys' need for flexibility and universal direction regarding when and how toselect corridor impact methods, data, and measurement technologies while still maintaining the integrity and consistency of the framework itself as the world changes.

New methods explicitly developed and tested in support of the Playbook include:

(1) **Corridor Orientation Methodology (Appendixes 7 and 8):** This tool was developed in collaboration agencies to test and validate an "orientation methodology" for navigating the overall process of corridor management set forth in the Playbook. Agencies have tested this methodology and its associated tool to (1) define the management effort and (2) specify the management regime and thereby (3) selectquantitative methods from the Corridor Management Playbook research appropriate to any given management effort. The result is the working tool and guidance in Appendixes 7 and 8.

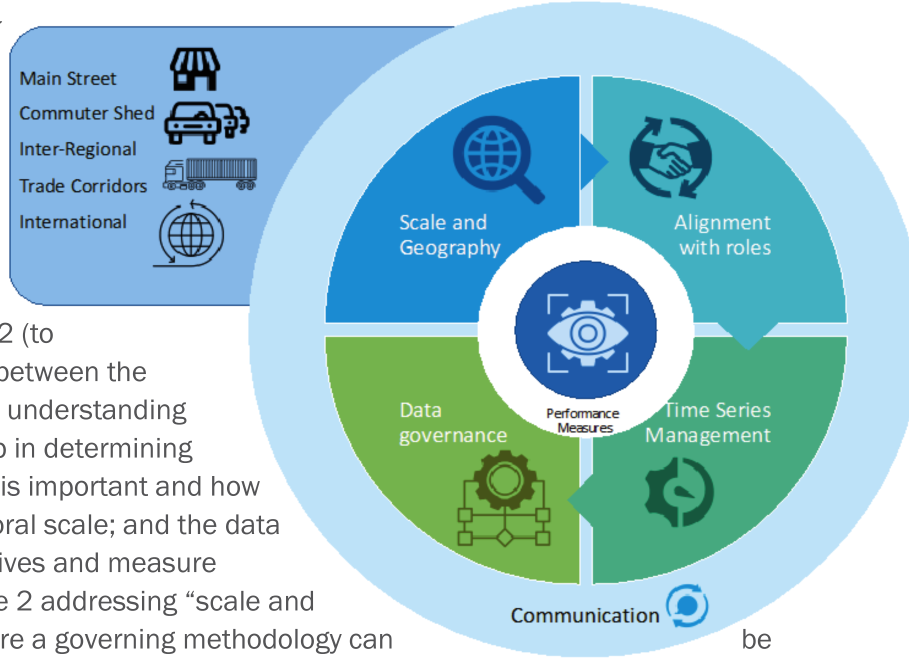
(2) **Corridor Impact Methods:** The validation process has entailed testing each of the proposed corridor impact methods given in Appendix 5, as shown in the test cases in that Appendix.

(3) **Statistical Validation Methods:** The 7-D methodology of the Playbook is the first time that the contextual land-use variables given in Appendix 10 and Appendix 11 have been shown with generalized marginal effects on corridor performance outcomes. For this reason rigorous statistical testing was applied and is documented in Appendix 11 to support this tool.



6.1 A Testable Corridor Orientation Methodology

One of the challenges in managing corridors for impact, is the great diversity in corridor geography, role/function, traffic composition, community characteristics, and modal composition. A core finding of the case research in Appendix 3 was the diversity of different levels of corridor management activities involving local, regional, inter-regional and national agencies and partnerships. The *Nested Scanning*case study approach in Appendix 3 found isolated examples where agencies are (sometimes inadvertently) managing corridors for both *form and function.* Unfortunately, few of these integratedapproaches have been framed as "corridor management," and most have not taken steps to effectively measure or balance corridor impacts for freight and passenger needs in urban areas related to land-use or urban design. In rural areas many corridor management activities have examined trade partnerships, but most have not taken steps to examine the true economic nature oftrade in corridors, the role of rural corridors as small-town main streets, or examined the multimodalnature of passenger movements in rural corridors.

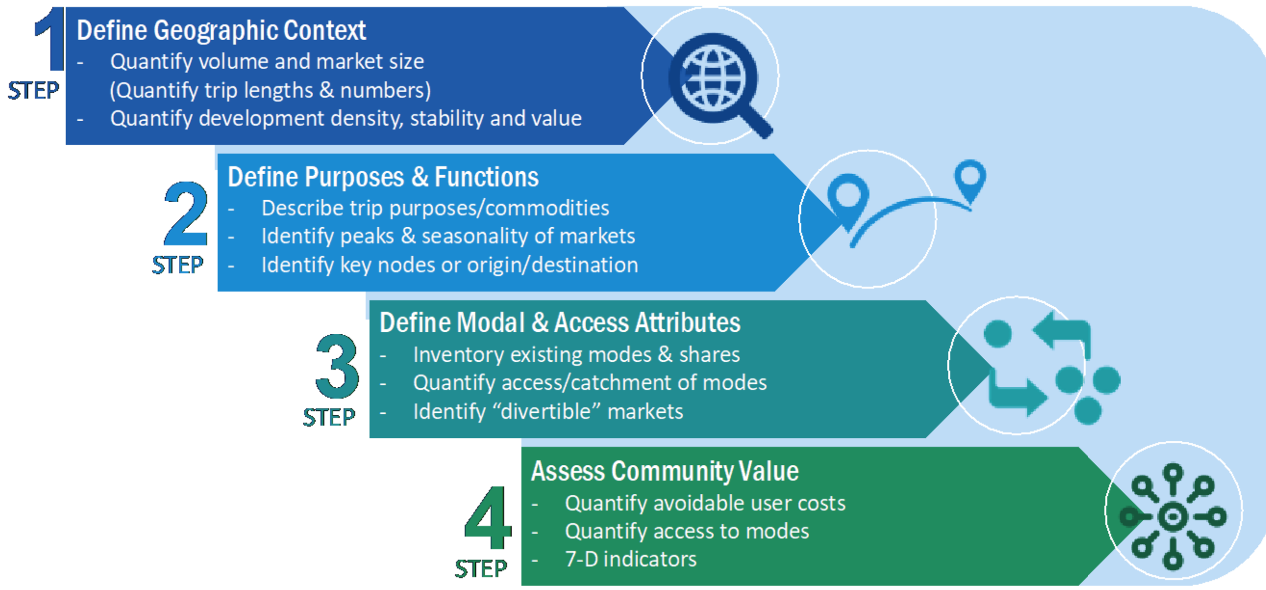


A *Nested Corridor Management Framework* provides corridor managers with a stepwise process of evaluating key corridor attributes and functions- establishing a contextual understanding of thenested corridor system. Figure 1 on the previous page provides a graphical representation of a potential Nested Corridor Management Framework. Figure 2 (to the right) demonstrates the relationships between the various components of such a framework- understanding scaleand functionality is a critical first step in determining stakeholders and establishing roles; what is important and how it will be measured; the appropriate temporal scale; and the data requirements needed to evaluate alternatives and measure performance. The upper quadrantof Figure 2 addressing “scale and geography” represent a starting point where a governing methodology can be tested to define how the rest of the framework may apply in a given setting.

Establishing corridor contextual understanding is an important first step in establishing a corridor management regime. Establishing context helps managing entities, and ultimately their stakeholders,explore concepts of value; what is important and why? A shared contextual understanding leads to a shared vision for the corridor system. From a shared vision, corridor goals, corridor objectives, and corridor impact measures are derived. Contextually appropriate quantifiable impact measures form the basis for evaluating corridor improvements and monitoring and measuring corridor performance. A well-thought-out vision, governance structure, and partnership can help overcome pressures to respond to short-term crises whose solutions may hinder long-term objectives. Below is the step-by-step process used to test and validate with sample agencies in 2021 to establish corridor context, starting with an evaluation of geography and functionality.

6.2 From Steps to Methods

The below description generally introduces a stepwise corridor orientation process, suggesting a starting point for data sources, methods, and variables to be applied and validated in work with subject agencies. It should be understood in reading these steps the testing process (1) utilized the entire suite of methods and tools identified in Appendixes 1-5 when testing out these steps with subject agencies and (2) sought to comprehensively map specific methods and tools to each step in the methodology through the validation/testing process. Every possible method that may be applied in any given step is not shown in the tables largely in theinterest of brevity, given that methods are comprehensively inventoried already in other appendixes.



6.3 Step 1- Define Corridors in Terms of Geographic Context

In the functional scheme, rural principal arterials serve corridor movements with long trip lengths and low relative trip density. At a high-level urban vs. rural freight/trade corridors can be understoodby the following corridor attributes:

- Trip length: Rural corridors, whether carrying passengers or freight, will have longer average trip lengths (e.g., exceeding 250 miles) between origin and destination. Average trip length is likely to vary by region. For example, Western Class 1 railroads typically view over 700 miles as the minimum length of haul for intermodal service, while Eastern Class 1 railroads will consider intermodal service at distances over 300 miles. Freight movements within an urban corridor are likely to be under 250 miles. Short freight movements in a corridor are also far more likely to be accomplished by trucks using "day-cabs" or single-unit vehicles.
- Trip Density/Freight Density: Most corridor management efforts focus on traffic levels as defined by vehicle miles traveled (VMT) or heavy-commercial vehicle miles traveled (HCVMT). To expand the corridor management context to include all modes may require examining metrics like ton-miles or total freight tons between origin-destination points on the corridor.

Within freight planning, the Freight Analysis Framework (FAF) provided by FHWA and BTS is a principal source of freight movement information. FAF commodity flows are presented for 132 domestic FAF zones. FAF zones are a combination of; 1) Combined Metropolitan Statistical Areas (CMSAs), 2) Metropolitan Statistical Areas (MSAs), 3) Rest of the state (everything not in a CMSA or MSA), 4 An entire state (no CMSA or MSA) or 5) A state wholly contained within an MSA. The entireFAF data set contains 132 origin/destination (O/D) points for the U.S. Examining corridors in relation to FAF Zones may be a good starting point for assessing commodity flows and understanding thesignificance of corridor from a freight perspective.

Public and private sector data ranging from NHTS to private (streetlight or NAVTEQ) data can servesimilar purposes for passenger traffic. However, it is expected that most long-distance corridor travel will represent the freight uses of the corridor.

Potential Metrics for Determining Geographic Context

Table 1 proposes some metrics that were applied, demonstrated, and tested in the creation of the orientation tool (documented in Appendixes 7 and 8) to developbenchmarks to determine the geographic context of corridors.

Table 1. General Characterizations of Trip Movements by Geography

Corridor Attributes	Data Sources - Passenger	Data Sources - Freight	Questions Addressed by Orientation Tool/Method
Total Traffic Volume / Trip density	AADT	HCAADT	What volumes are typical of urban/rural corridors. What arethe percentages of passenger vs. truck trips
Trip Length	GPS data	Truck GPS data Commodity FlowSurvey/FAF Shipper Bill of Lading (BOL)	What is the average length of commuter and e-commerce trips vs. business/vacation travelor B2B freight movements
Land-use	Parcel Data	Business Establishment Data, Shipper BOL	What are the land-use characteristics of commuter travel sheds and warehouse distribution activities

6.4 Step 2- Define Corridors in Terms of Primary and Secondary Purpose/Function

For decades transportation planners have relied on the FHWA *Functional Classification System* as keycriteria for monitoring and measuring the nature of trips on the nation's highways. According to the FHWA Functional Classification Guidelines:

> *Functional classification is the process by which streets and highways are grouped into classes, or systems, according to the character of service they are intended to provide... most travel involves movement through a network of roads. It becomes necessary then to determine how this travel can be channelized within the network in a logical and efficient manner. Functional classification defines the nature of this channelization process by definingthe part that any particular road or street should play in serving the flow of trips through a highway network.*

This definition provides a context for highway trips but is not directly applicable to multimodal corridor management due to its mono-modal nature. However, it does provide one approach for developing a potential functional context for corridor management; another approach is end-use.

- End-Use: In addition to the length of trips in a freight corridor, the nature of trip movement will also differ between urban and rural. Rural freight corridors are most likely to carry business-to-business (B2B) freight movements: Raw materials, capital goods, and Intermediate goods are all largely B2B trade elements of the economy tracked by the Bureauof Economic Analysis. These product accounts are inputs to the economy that could also be used to examine the nature of a corridor and how it is managed for freight movement. Within urban freight corridors, business to retail distribution or business to consumer (B2C) movements are likely to dominate the nature of trips. These retail distribution or B2C trips are also where last mile issues typically arise.

Potential Metrics for Determining Functional Context

Table 2 proposes some metrics applied to develop benchmarks todetermine the functional context of corridors.

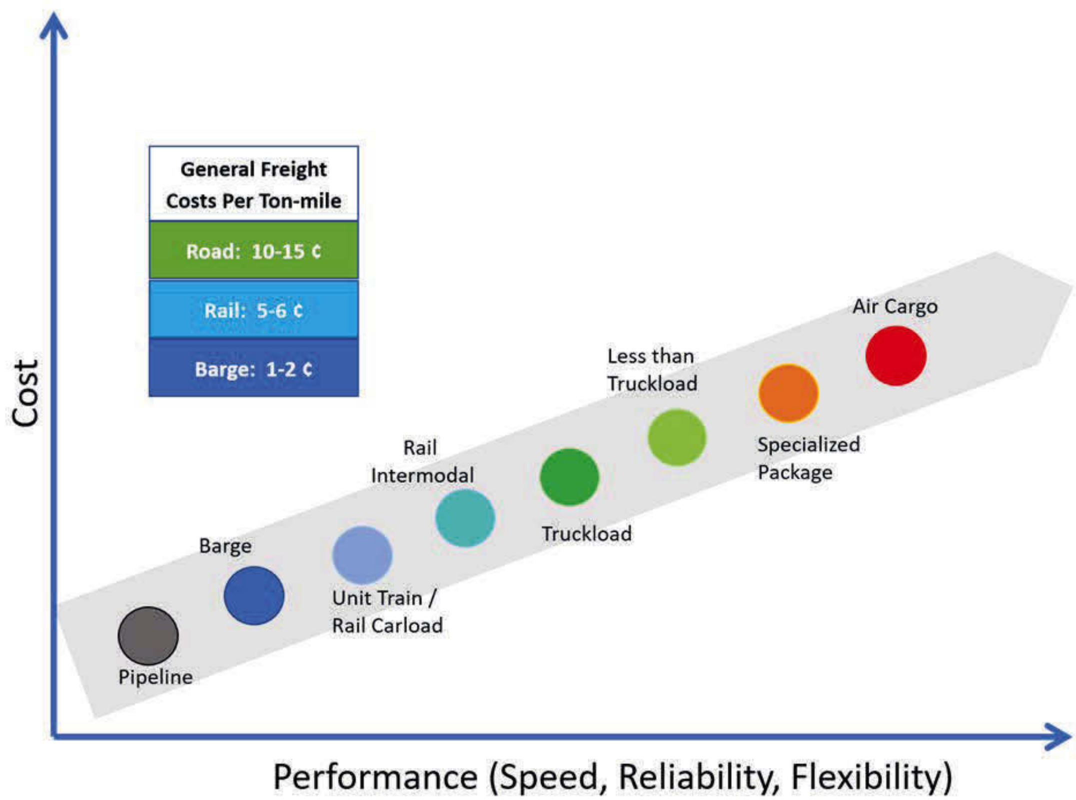
Table 2. General Characterizations of Trip Movements by Function

Corridor Attributes	Data Sources - Passenger	Data Sources - Freight	Questions Addressed by Orientation Tool/Method
Trip Purpose/Type	GPS data Employment, Demographi cdata Land-use Parcel Data	Truck GPS data Shipper BOL Employment Data Business Est. Data	What is the breakdown of trips by purpose: e.g., home to work,home to school, shopping, recreation, B2B, B2C-Ecommerce, hub-to-hub linehaul, etc.
Peak Travel	AADT	HCAADT	What are the characteristics of peak travel by geography?
Trip Balance	GPS data	Truck GPS data	What are the characteristics of trips by origin and destination?

6.5 Step 3- Define Corridor in Terms of Modal/Alternatives Access

Another key step in understanding corridor management for freight is understanding the modes andservices available within a corridor. In general terms, each mode of freight transportation provides amix of cost, speed, accessibility, and flexibility that shapes its service attributes and offerings. Serviceneeds also play a major role in determining the mode(s) used by specific industries for the commodities they consume and produce. For example, air cargo services are most often used to transport products with a high value to weight ratio (e.g., computer chips) or products that are incredibly time-sensitive (e.g., fresh flowers) and/or require a high level of flexibility (e.g., on-site replacement parts). At the opposite end of the modal spectrum, pipelines are very inflexible and usually handle only a single product, moving in one direction. Barges usually transport products withlow time sensitivity (e.g., sand, gravel, road salt). Commodities moving by pipeline and barge typically have a low value to weight ratio. Figure 3, shows a typical array of modal services present in a corridor along with the general service attributes that define modal options.

Figure 3: Modal Service Attributes and Cost



Competition between service and price tends to be greatest the closer the modal options are on the spectrum. However, access to a particular service may alter its ability to substitute for a similar service within a corridor, especially when initial capital costs are high. The global nature of trade and the long distances many products move often results in multiple modes to achieve the best price andservice mix. So, in corridors with high truck traffic, services like intermodal rail or rail carload/transload are likely to be the most competitive alternatives to reduce truck traffic. However,trucking services' flexibility and door-to-door attributes make trucking the undisputed choice for “last-mile” deliveries in urban corridors.

Products depend on different transport services based on length of haul, inventory holding costs, weight, perishability or shelf-life, fragility, and sensitivity to market conditions. For example, medical devices (e.g., pacemakers) have a high cost-to-weight ratio, high inventory holding costs, and time-definite delivery windows measured in minutes and hours. These conditions are best met by the services specialized package and air cargo carriers routinely provide. Conversely, grain has a low cost-to-weight ratio, low inventory holding costs, and delivery windows measured in days instead of hours.These factors make low-cost barge or rail services more suitable for grain transport. Air cargo and expedited truck delivery services may cost thousands of dollars on a weight basis versus barge andrail services, which are more likely to have cost measured in cents.

Potential Metrics for Determining Modal Access

Table 3 proposes some metrics to be addressed by the orientation tool to develop benchmarks to determine theaccess to non-auto/truck alternatives within corridors.

Table 2. General Characterizations of Trip Movements by Function

Corridor Attributes	Data Sources - Passenger	Data Sources - Freight	Questions Addressed by Orientation Tool/Method
Distance to bus transit	GIS Analysis	N/A	Are non-auto alternatives reasonably available?
Distance to rail services (commuter, light rail,freight rail yards	GIS Analysis	GIS Analysis	Is the overall catchment (same-day delivery radius) of a key inter-modal facility sensitive tochanges made in corridor connections or capacity?
Distance to barge/port	GPS data	Truck GPS data	
Percentage of trips by mode		CFS/FAF BOL	Is there a divertible freight or passenger market? If so, what modes, trip purposes or commodities represent that market? To what corridor attributes are divertible marketssensitive?

6.6 Step 4- Define Corridors in Terms of Community (Mainstreet)

At the origin and destination ends of a nested corridor system are neighborhoods and communities with distinctive characteristics and visions that may have little to do with a broader system of corridors and regional or interstate economic outcomes. Nevertheless, these communities play a crucial role in the overall effectiveness and efficiency of the corridor system. The 7-D concepts are treated explicitly with respect to marginal effects on corridor performance in Appendix 10 and Appendix 11 but are also addressed in Appendixes 7 and 8 as performance indicators for defining a corridor. By understanding how important these concepts are to the community, stakeholders will help determine the set of performance impact measures used to measure success.

	7-D's for Passenger Movements	**D's for Freight Movement**
1	Density of Development	Density of business establishments
2	Diversity of Land-uses	Diversity of support services (freight village concept)
3	Design of Streets	Design of infrastructure
4	Destination Accessibility & Connectivity	Destination Accessibility & Connectivity
5	Distance from Transit & Modal Connections	Distance from modal connections
6	Demographics	Industry clusters
7	Demand Management	

6.7 Corridor Orientation Profiles & Typologies

The above-described corridor orientation methodology yields a 4-component corridor orientation profile (used in the orientation tool given in Appendix 7), which agencies can then use to determine the scope of the management effort. The application and testing of this 4-step orientation process yields a reasonable spreadsheet-driven process by which a corridor can be given a score for each of the components identified in the four steps. The outcome is the spreadsheet tool (APP 7) matching a corridor's profile [in terms of (1) geographic market size, (2) purpose/function, (3) modal/access attributes, and (4) community needs]

Step	Criteria/Quantifiable Indicators	Outcome Possibilities (Categories)	Code
Step 1: Corridor Size & Market	Volume, Distance, Number of Trade Centers, etc.	Rural- Dense	10
		Rural- Sparse	11
		Urban Dense	12
		Urban Sparse	13
		Mixed/Transitioning	14
Step 2: Purposes & Function	Peak/Seasonal Distribution, Trip Purposes/Commodity Distribution, concentration of trip ends	Year-Round Freight	20
		Year-Round Passenger	21
		Seasonal Freight	22
		Seasonal Passenger	23
		Year-Round – Both	24
		Seasonal - Both	25
Step 3: Modal Access - Divertible	Modal Shares, Divertible %, Modal Access Quality/Catchment	Unimodal	30
		Multimodal - Freight Divertible	31
		Multimodal - Passenger Divertible	32
		Multimodal - All Divertible	33
		Multimodal - Non-Divertible	34
Step 4 - Context	Cost of Access, Distance to Transit, Stability of Development, Community/Development Value	High Local Impact	40
		Medium Local Impact	41
		Low Local Impact	42
		No Local Impact	43
*The **4- Component Profile** is a Composite of the Four Codes. A suggested suite of indicators and methods (from the research shown in Appendixes 1-5) are offered in the Playbook for each profile. An interactive M.S. Excel tool (APP 7) facilitates selecting the profile based on user input - informed by methods to be applied/tested in 2021.*			

In the above example; a corridor may be 10-20-30-40 (in the spreadsheet); defined as a dense-rural,year-round (non-seasonal) freight, unimodal (truck), High-local impact corridor. This type of testing is the basis of the tool and methodology given in Appendixes 7 and Appendix 8 Orientation Tool User Guidance.

Appendix 7
Corridor Orientation Tool Interactive File (xls)

The interactive Corridor Orientation Tool is available on the National Academies Press website (nap.nationalacademies.org) by searching for *NCHRP Web-Only Document 386: Quantifying the Impacts of Corridor Management*.

Appendix 8
Corridor Orientation Tool User Guidance

8.1 Background

Corridors range from short urban arterials to freeway corridors of nationally significant lengths. The best practice means of approaching corridor management varies significantly depending on geography and scale, purpose and functions, availability and attractiveness of alternative modes, and adjacent land-use and community integration. An orientation tool within Microsoft Excel has been developed to help practitioners structure best-practice approaches to corridor management. This memo describes that tool and how to use it correctly. In addition to this document, there is an "Instructions" tab in the spreadsheet.

8.2 Hypothetical Example: I-95, Boston to Washington D.C.

The orientation tool can be used for any kind of corridor and many purposes – rural or urban; passenger, freight, or both; local arterials or multimodal national corridors. For illustration, these instructions are set to evaluate I-95 from Boston to Washington.

8.3 Step 1 – Geographic Context

8.3.1 Step 1a

Below are the settings for this corridor. The 450-mile length was determined from Google Maps. This example focuses only on freight, for brevity. Notice the rows on both sides are labeled 1-18. These are different from the Excel numbered rows, and are used only to help you to internally reference a location in any given table.

Step 1: Geographic Context

#	Geographic Scale and Complexity		
2	Corridor Name	I-95	
3	Start Point	Boston, MA	
4	End Point	Washington, DC	
5	Length (miles)	450	
6	Primary Focus?	Freight Focus	
7	Are multiple states involved?	Yes	
8	Are multiple counties involved?	Yes	
9	Are multiple communities involved?	Yes	
10	US Region	Northeast	
11	What best describes the study area?	Counties / Cities	
12	Are Rural issues a significant concern?	No	
13	Are Urban issues a significant concern?	Yes	
14	Are there racial or equity concerns?	Yes	
15	Inter- or Intra-Regional?	Inter-Regional	
16	Inter-Regional Context:	C6: Large centers + suburban	Use Inter-Regional Worksheet
17	Intra-Regional N/A		
18			

On row 15, it asks if the corridor is Inter-Regional or Intra-Regional. The latter is usually for shorter corridors contained within a single urban area, or a 1 or 2-state rural corridor that links small communities. Selecting "Inter-Regional" brings up a link to the "Inter-Regional Worksheet" (or just click the correct tab).

8.3.2 Step 1b – Inter-Regional Worksheet

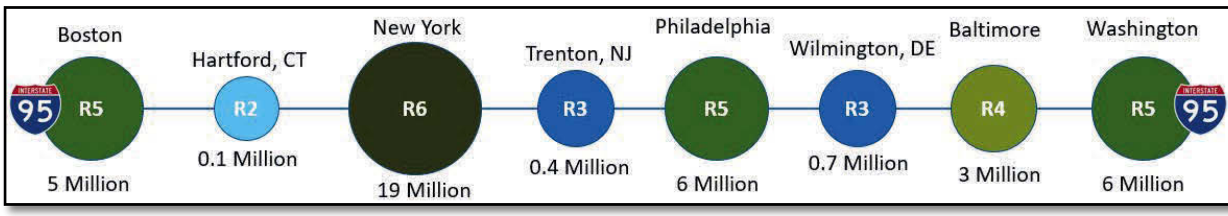
The purpose of this sheet is to help you determine which of the following inter-regional corridor types best matches your corridor.

Inter-Regional Corridor Descriptions	Pop/Mile-Min	Pop/Mile-Max	Example
C1: Rural / Wilderness	1	500	US 50, Nevada
C2: Small centers + long rural	500	5,000	US 50, Pueblo, CO to Wicheta, KS
C3: Small centers + short rural	5,000	10,000	US 64, Charlston, WV to Lexington, KY
C4: Large centers + long rural	10,000	30,000	I-85, Charlotte NC to Raleigh, NC; I-15, Las Vegas to Salt Lake
C5: Large centers + short rural	30,000	60,000	I-95, Orlando to Miami
C6: Large centers + suburban	60,000	100,000	I-95, Boston, MA to Washington, DC

A C1 corridor is mainly rural. Any towns along it will likely have populations less than 10,000. A C2 connects larger communities, probably above 10,000 and below 100,000, with relatively long distances between these larger communities. C3 has community sizes similar to C2, but the distance between communities is much shorter. C4's connect large cities with long distances between them, and C5's are similar but have short distances between them. C6's connect huge "Megacities" and the areas between Megacities are mainly suburban, with relatively little open space.

As every corridor is a combination of big and small cities, with varying distances between, it is not very easy to determine if the corridor is C3 or C4, for example. To aid in determining the "Population per Linear Mile" an index was created with the breakpoints shown in the table above. Thresholds were determined by testing many corridors across the country to see how well the pop/mile breakpoints matched the C1 to C6 text definitions.

1	Regions connected by I-95 between Boston, MA and Washington, DC						1
2				See Boston to Washington example at right			2
3	MSAs Connected, in order	Population - 2019	Region Size	Total population			3
4	MA, Boston	4,900,000	R5: Global				4
5	CT, Hartford	1,200,000	R4: Metro				5
6	NY, New York	19,000,000	R6: Megacity	MSA Categories	Pop-Min	Pop-Max	6
7	NJ, Trenton	370,000	R3: City	R2: Town	10,000	100,000	7
8	PA, Philadelphia	6,100,000	R5: Global	R3: City	100,000	1,000,000	8
9	MD, Baltimore	2,800,000	R4: Metro	R4: Metro	1,000,000	3,000,000	9
10	DC, Washington	6,300,000	R5: Global	R5: Global	3,000,000	10,000,000	10
11	Select a Region	0	0	R6: Megacity	10,000,000	30,000,000	11
12	Select a Region	0	0	*MSA = Metropolitan Statistical Area			12
13	Total linked by corridor	40,670,000					13
14	Reported miles of corridor	450	(From Step 1)				14
15	Pop per linear mile index	90,400	C6 (Probable corridor type based on pop per linear mile)				15
16	C6: Large centers + suburban	<= Do this: Select a best-fit inter-regional corridor descriptor					16
17		based on values in green box above and on examples below.					17



To determine your index, you first identify all of the MSAs that your corridor links together. The tool sums the population and divides it by the distance between the first and last city. In the Boston to Washington example, this corridor is C6 because it has about 90,000 people per linear mile. See the worksheet below for how this is computed.

Computing Pop per Linear Mile

In this worksheet, you use rows 4-12 to identify all of the Metropolitan Statistical Areas that are linked by the corridor. These are drop-down boxes where you select the MSA, then the 2019 population and region size definition (R2 to R6) are automatically populated. If the corridor is mainly rural and has no MSAs, leave rows blank and go directly to Row 16 and select “C1: Rural/Wilderness”. Row 13 is the total population of the MSAs linked by the corridor. Row 14 is the distance between first and last. Row 15 is then the population per mile. In red text, the tool determines that this is a C6 corridor because 90,400 pop/mi falls into the C6 category.

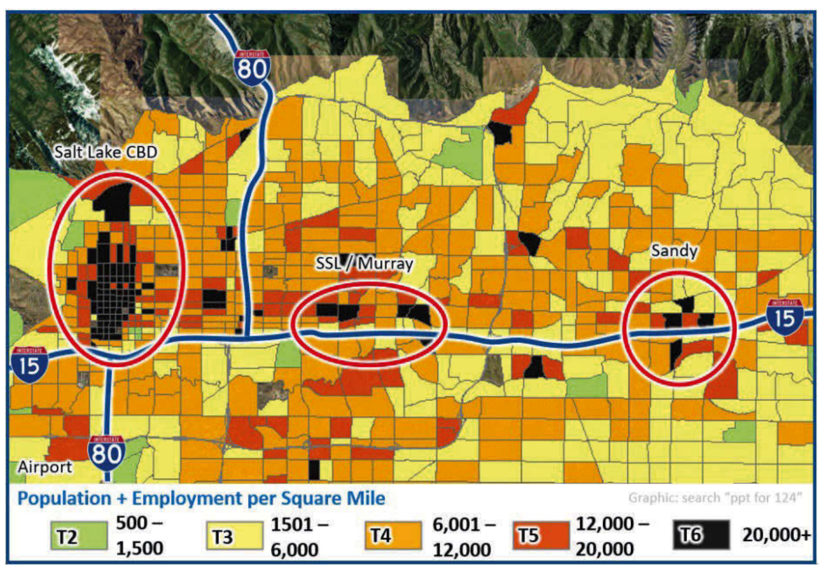
Then in Row 16, you will manually select C6 if you agree with the default, or you can select C5 if you think that is a better definition. Further instructions are embedded within the tool.

8.3.3 Step 1c – Intra-Regional Worksheet

Intra-Regional analysis is usually for corridors where the start-point and endpoint of analysis are contained entirely within a single urban area, even if the corridor is also part of a larger inter-regional corridor (such as an interstate freeway). Intra-regional analysis depends on defining sub-districts as the "Transect" type that best defines them today, as well as the best definition that is being planned for at a 30-year planning horizon or at buildout.

How to Define and Classify Districts in GIS

In this example of I-15 in Salt Lake County, there are three significant districts as well as a fourth "general suburbs" district to represent everything else. Within GIS, we computed the present and future "Population + Employment per Square Mile" for each Traffic Analysis Zone (TAZ). Using the results, the T2 to T6 density thresholds were established as shown in the legend.



Then within the tool, as shown below, we defined each district and manually defined each district as T3 to T6 based on a "gut feel" of the average of the various TAZs. (Alternatively, dissolve boundaries of the district TAZs to get an exact pop+emp per SqMi).

	Intra-Regional Worksheet							
	Subregional Districts				**PEpSM-Est**	**PEpSM-Est**	**PEpSM-GIS**	**PEpSM-GIS**
	District Names		**Present Type**	**Future Type**	**Present**	**Future**	**Present**	**Future**
	General suburbs		T3: Suburban	T3: Suburban	1501 to 5000	1501 to 5000	(if available)	(if available)
	Sandy Town Center		T4: Urban	T5: Urban Center	5001 to 10000	10001 to 20000		
	Murray Town Center		T3: Suburban	T5: Urban Center	1501 to 5000	10001 to 20000		
	Salt Lake CBD		T6: Urban Core	T6: Urban Core	20001 to 200000	20001 to 200000		
	District 5		T#	T#	0	0		
	District 6		T#	T#	0	0		
	District 7		T#	T#	0	0		
	District 8		T#	T#	0	0		
	District 9		T#	T#	0	0		
0	T1: Natural	1	T4: Urban		This area lists relevant contexts for text concatination. Ignore.			
0	T2: Rural/Trans	1	T5: Urban Center			T4,		
1	T3: Suburban	1	T6: Urban Core			T5,		
					T3,	T6,		
	All relevant contexts:		**T3, T4, T5, T6,**	(Formula reflecting blue box choices)				

How to Define and Classify Districts by "Educated Guess"

The tool merely wants your estimate of the present and future conditions for each district. To save time over computing this in GIS, you can simply use the Transect definitions and illustrative photos to estimate what the district is like today, and what you believe it likely will become in the future based on market trends and ongoing planning efforts.

Checking the "Blue Boxes"

After defining present and future districts, manually enter "1" into each blue box if the corridor presently has, or will have, that transect type. After completing blue boxes, Row 19 automatically concatenates each transect to report back to the broader tool which types of uses your corridor management efforts should be addressing.

8.4 Step 2: Purpose and Functions

There are separate Excel tabs for Steps 2-4 for both Passenger and Freight. This documentation shows passenger and freight together so you can easily see the differences. In Step 2, you define total corridor AADT for passenger traffic and Heavy Commercial (HC-AADT) for trucks. In the blue boxes, you define the level of importance or scale of the problem where 1 = above average importance, 2 = average, and 3 = below average or not a topic of heavy interest to your stakeholders or to your management strategy. In the tool's recommendations, it weights 1's heavier than 2's, suggesting 1's are likely to be "top priorities" for your stakeholders, 2's are important and can't be ignored, and 3's are either functioning just fine or not of strong interest at the moment.

Step 2: Purposes and Functions, Passenger Travel

Passenger Corridor Purpose Assessment

Corridor Length: 450 miles — Typical AADT (see note) 200,000

Level of Importance (1-3)		Scale of Problem (1-3)	
1	Inter-Regional / Thru-Trips	1	Congestion / Mobility
2	Commute Trips	2	First/Last Mile Access
3	Shopping, Circulation, Services	3	Challenges w/ Safety
3	Recreation	1	Challenges w/ Resiliency
3	eCommerce	2	Financing Preservation
2	Emergency evacuation		

Blue cells: Importance or significance of the topic to corridor managers and likely stakeholders. 1 = above average, 2 = average, 3 or blank = below average or not relevant.

ITS Features		Other Topics	
1	Connected / Autonomous Vehicles	2	Peak period volumes
2	Traffic Management Centers	2	Peak shipping season volumes
3	Variable Message Signs		
3	Road weather information systems (RWIS)		
3	511 Road / Traveler Information		

Step 2: Purposes and Functions, Freight

Freight Corridor Purpose Assessment

Reported Area Type: Inter-Regional (Step 1) — Typical HC-AADT (see note) 8,000

	Prioritize by Interest	Min Miles	Max Miles
1	Long-haul	500	3,999
2	Medium-haul	250	499
3	Short-haul	100	249
4	Very Short-haul	1	99

Orange Cells: Rank from 1-4 the most common or critical trip types to address (1 = most critical, do not reorder rows).

	Prioritize truck trip types to be studied or managed.			Other Topics
4	Thru-trips	Yes	3	Peak period volumes
2	Business-to-Business	No	1	Peak shipping season volumes
3	Business-to-Consumer	No	1	Need for off-peak / evening delivery
1	First / Last-mile	NA	2	Empty / underloaded trucks
			3	Weight / size restrictions
			3	Extreme weather effects

	ITS Features
	Connected / Autonomous Vehicles
	Traffic Management Centers
	Variable Message Signs
	Road weather info systems (RWIS)
	511 Road / Traveler Info

Blue cells: Importance or significance of the topic to corridor managers and likely stakeholders. 1 = above average, 2 = average, 3 or blank = below average or not relevant.

8.5 Step 3: Alternative Mode Options

For addressing passenger travel demand in a corridor, it is important to know what kind of roadway types are available for travel in the corridor, or that are being contemplated if not already there, as well as any transit and active mode features. In the blue boxes, place a 1 or 2 next to anything that seems relevant, either because it is already available in the corridor or there is potential for it and stakeholders are interested in it. 1's are weighted more heavily than 2's, meaning you consider anything with a 1 to be a higher priority than 2's. 3's and blanks are treated the same, basically, the tool does not add any points toward topics that are blank or rated as a 3.

In a long inter-regional corridor like Boston to Washington, researching options for premium streetscape and protected cycle tracks along localized arterials near the I-95 corridor may be out of scale and better addressed in a different context. However, it is also possible that a broad multistate corridor coalition could see value in emphasizing how to improve short, localized travel along the corridor by alternative modes as a strategy for removing trips from the larger corridor.

Step 3: Mode and Access Attributes, Passenger Travel

Access to Alternative Modes or Paths

Passenger Vehicles: Options for Alternative Modes

	Vehicle features in the corridor		Transit Features		Active Mode Features
1	Interstate Freeway	1	Commuter Rail	2	Cycle: Protected
3	Intrastate Freeway	3	Light Rail / Streetcar		Cycle: Painted
1	Tollway	1	Amtrak	1	Sidewalk: Premium
2	Toll or HOV lanes		Bus Rapid Transit		Sidewalk: Basic
	At-grade Expressway	1	Bus - Intercity		
1	Principal Arterial	1	Bus - Commuter Exp.		
	Minor Arterial		Bus - Standard		
	Rural County Roads		Fare-Free Circulators		
		1	Airlines		

Blue cells: Importance or significance of the topic to corridor managers and likely stakeholders.
1 = above average, 2 = average, 3 or blank = below average or not relevant.

Step 3: Mode and Commodity Attributes, Freight

Access to Alternative Modes or Paths

Freight: Options for Alternative Modes

	Truck opportunities in the corridor		Alternative Modes		Commodity Description
1	Interstate Freeway		Pipeline	2	Advanced
	Intrastate Freeway	2	Barge / Maritime	1	Consumer Goods
2	Tollway, Tolled Lanes	1	Rail - Class 1	2	Dry Bulk
	Truck-Specific Lanes, Routes		Rail - Transload		Dry/Liquid Bulk
	At-grade Expressway		Air Cargo		Heavy Manufacturing
	Principal Arterial				Light Manufacturing
	Minor Arterial				Liquid Bulk
	Rural county roads				

Blue cells: Importance or significance of the topic to corridor managers and likely stakeholders.
1 = above average, 2 = average, 3 or blank = below average or not relevant.

For freight, commodities are organized into seven broad categories, each with different divertibility potential.

See Commodity Diversion Worksheet for details

SCTG/FAF Commodity Codes		Divertible to:			
Code	**Commodity Description**	**Air**	**Rail**	**Water**	**Examples**
1	Advanced	Yes	No	No	Animals, Pharma, Instruments
2	Consumer Goods	No	Yes	No	Store items, packaging, misc.
3	Dry Bulk	No	Yes	Yes	Gravel, coal, grain, etc.
4	Dry/Liquid Bulk	No	Yes	Yes	Fertilizers, plastics, fats/oils
5	Heavy Manufacturing	No	Yes	Yes	Wood, mining, waste, etc.
6	Light Manufacturing	No	Yes	No	Textiles, machinery, vehicles, furnature, etc.
7	Liquid Bulk	No	Yes	Yes	Chemicals, fuels

8.6 Step 4: Community Integration

A significant objective of this research is to improve the ability of corridor managers to integrate well with, and even positively influence, land-use, equity, sustainability, and economic vitality objectives of surrounding communities, to the extent that this may be possible with the tools they have available. In this section, the "7D's of Place Making" are emphasized for passenger travel, along with other community needs and issues as shown. For freight, a slightly different set of 7D's has been created to help guide how freight can better integrate with communities.

In each case, each of the 7D's has a red triangle in the corner. Hover over the triangle and it will provide a comment on what that particular D variable means so you can more easily determine how to respond to it.

Step 4: Community Integration, Passenger Travel

Managing corridors for economic vitality, sustainability, and equity

	7Ds of Place-Making (See Notes)		**Community Needs / Issues**
1	1 Density	2	Address climate change
2	2 Diversity	2	Reduce long-term costs
2	3 Design	1	Prepare for automation
1	4 Destinations	1	Improve alternative paths
2	5 Distance from Transit	1	Involve stakeholders
2	6 Demographics	2	Address Equity
2	7 Demand Management		Natural Environment
			Growing population?
			Shrinking population?

Blue cells: Importance or significance of the topic to corridor managers and likely stakeholders.
1 = above average, 2 = average, 3 or blank = below average or not relevant.

Step 4: Community Integration, Freight and Delivery

Managing freight for economic vitality, sustainability, and equity

	7Ds of Freight		**Community Needs / Issues**
1	1 Density of Business Activity	1	Address climate change
1	2 Diversity of uses	2	Reduce shipping / infra. costs
2	3 Design of Infrastructure	2	Prepare for automation
1	4 Destination Accessibility	1	Improve alternative paths
1	5 Distance to Alternative Modes	1	Involve stakeholders
2	6 Demography of Corridor Uses	1	Address Equity
2	7 Demand Mgt Regulations	1	Air Quality (diesel exhaust)

Blue cells: Importance or significance of the topic to corridor managers and likely stakeholders.
1 = above average, 2 = average, 3 or blank = below average or not relevant.

8.7 Processing and Results

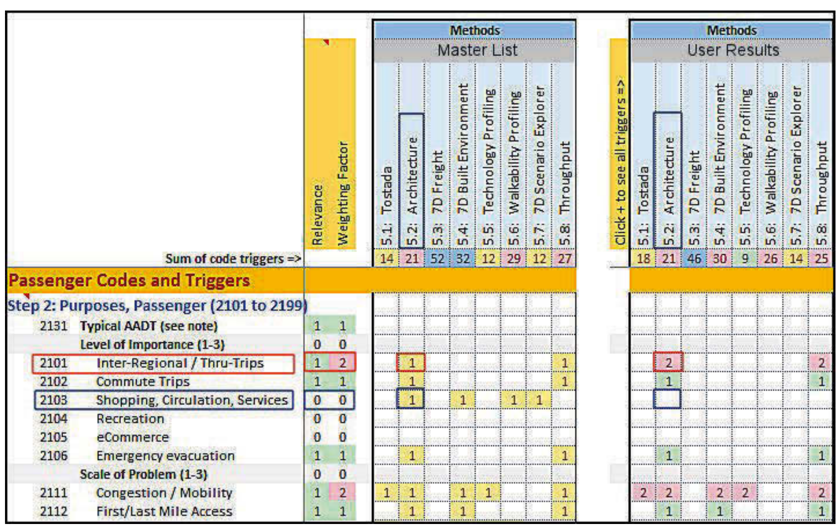
After you have completed all steps, look at the tabs called "Results-Passenger" and "Results-Freight." This is effectively a restatement of your answers, in a standardized row and column format that will be easier for the tool to assign lookup codes for further recommendations.

At the right is a segment of that tab for Step 3. The levels of importance are repeated. Anything rated as 3 is considered the same as blank, or as zero. The "Show" column has a drop-down arrow where you can hide all the rows with red zeros because these rows are not relevant to your corridor analysis or management effort. There is also a "Code" field, which is used later as a lookup to tie your responses to specific corridor management and analysis opportunities.

	Field	User Response	Code	Show	
1	Corridor Management Guidance Tool: User Defined Context			1	1
	Step 3: Mode and Access Attributes, Freight			1	
61	Access to Alternative Modes or Paths			1	61
62	Field	User Response	Code	1	62
63	Truck options in corridor	Importance (1-3)		1	63
64	Interstate Freeway	1	3201	1	64
65	Intrastate Freeway	0	3202	0	65
66	Tollway, Tolled Lanes	2	3203	1	66
67	Truck-Specific Lanes, Routes	0	3204	0	67
68	At-grade Expressway	0	3205	0	68
69	Principal Arterial	0	3206	0	69
70	Minor Arterial	0	3207	0	70
71	Rural county roads	0	3208	0	71
72				0	72
73	Alternative Mode Availability	Importance (1-3)		1	73
74	Pipeline	0	3211	0	74
75	Barge / Maritime	2	3212	1	75
76	Rail - Class 1	1	3213	1	76
77	Rail - Transload	0	3214	0	77
78	Air Cargo	0	3215	0	78
79				0	79
80	Commodity Scale	Importance (1-3)		1	80
81	Advanced	2	3221	1	81
82	Consumer Goods	1	3222	1	82
83	Dry Bulk	2	3223	1	83
84	Dry/Liquid Bulk	3	3224	0	84
85	Heavy Manufacturing	3	3225	0	85
86	Light Manufacturing	0	3226	0	86
87	Liquid Bulk	0	3227	0	87

8.7.1 Applying the Codes

A tab called "Codes and Methods" contains all of the potential codes, and the methods, stakeholders, goals, metrics, and data sources that are relevant to that code. Shown here, the "Relevance" column (green 1's and white 0's) shows all of the codes that are relevant to your corridor based on your responses. The "Weighting Factor" column is either a red 2 or green 1. Anything that you said was a high priority gets a 2. Normal priority is 1. Lower priority topics or irrelevant topics all have zero.



Notice there are two "Methods" blocks in blue. The first block with yellow 1's is the master list, where a yellow 1 means "Yes, this method is helpful for addressing the topic associated with the code." The second Methods block multiplies the yellow 1's by both the relevance and the weighting factor. For example, look at code 2101 (Thru-trips) which is featured in red rectangles, the first block shows a yellow 1 under "5.2 Architecture". The second block, User Results, shows a red 2 under Architecture. The relevance column says the user has indicated that Code 2101 is relevant to their study. A weighting factor of 2 means the user considers it extremely relevant. Thus the green 1 (relevance) x red 2 (weight) x yellow 1 (architecture) = a red 2 as the User Result. Looking at code 2103 (shopping) featured in blue rectangles, the Master List shows a yellow 1, meaning "Yes, 5.2 Architecture method is relevant to managing shopping trips." However, the User Result is blank for this topic, because the user did not consider shopping trips of high enough interest for their management or analysis effort.

8.7.2 Final Recommendations

On the Recommendations tab, the column format for Methods, Stakeholders, Goals, Metrics, and Data Sources shown earlier for the "Codes and Methods" tab, is converted to a Row format using a Transpose function in Excel. The results are shown below.

Triggers activated by user responses		Psnger	Freight
Methods	5.1: Tostada	1	1
	5.2: Architecture	0	0
	5.3: 7D Freight	1	46
	5.4: 7D Built Environment	0	0
	5.5: Technology Profiling	0	0
	5.6: Walkability Profiling	1	1
	5.7: 7D Scenario Explorer	1	1
	5.8: Throughput	0	0
Stakeholders	FHWA (highways)	3	29
	FTA (transit)	1	1
	MARAD (waterways)	0	20
	FRA (railroads+private)	1	22
	DOT (state-level)	4	43
	MPO	3	42
	RPO	0	32
	County Gov	2	34
	City Gov	3	37
	Local Transit Agencies	2	2
	Business or Neighborhood Reps	1	8
	Environmental Interests	1	5
	Active Mode Interests	1	5
	Equity Interests	2	25

Triggers activated by user responses		Psnger	Freight
Historic Goals	Improve Safety	0	13
	State of Good Repair	0	13
	Reduce Congestion	0	14
	Environmental Quality	0	15
Emerging Goals	Multimodal Accessibility	1	22
	Economic Vitality	1	28
	Livability, Walkability	1	19
	Resiliency	0	21
	Equity	1	21
Historic Metrics	Fatalities, Serious Injuries	0	9
	Cost of Maintenance	0	12
	Vehicle Delay	0	21
	Mobile Emissions	0	18
Emerging Metrics	Mode Split / Accessibility	1	23
	Land Use Vitality	1	21
	VMT per Capita (7Ds)	1	1
	Reliability Indices / Fluidity	0	32
	H + T Affordability	1	1
Data Sources	Commodities (FAF, Transearch...)	0	15
	GPS (HERE, ATRI, Private)	0	19
	Bill of Lading / Waybill	0	15
	Traffic Vol (HPMS, WiM)	0	10
	Land Use, Parcel	0	16
	Businesses (Info USA, etc.)	0	18
	Additional Source	0	0

Your responses in steps 1-4 trigger various codes on the "Codes and Methods" tab, suggesting that the topic appears to be relevant to that particular response. A "42" under freight for MPO means that counting weights, the number of codes where the MPO is relevant added up to 42.

Thus, the totals under the Passenger and Freight columns give some indication of the likely relevance of that topic to your corridor. Green is fewer than 10 triggers activated by your responses.

Yellow is 11-20, red is 21-30, and blue is above 31 triggers activated. A category with 10 triggers is not necessarily 4x less important than a category with 40. It may mean that a particular category simply doesn't have 40 triggers available even if all triggers were activated.

For example, MARAD (federal waterway oversight) is likely to have far fewer triggers than a state DOT which is involved in almost everything, even if the corridor has strong reasons to have MARAD at the table. In general, the totals should give some idea of how important each of the topics is to the corridor. Thus, there is some need to examine the results to determine how well they reflect your understanding of what is needed for corridor management and analysis.

8.8 Using the Results

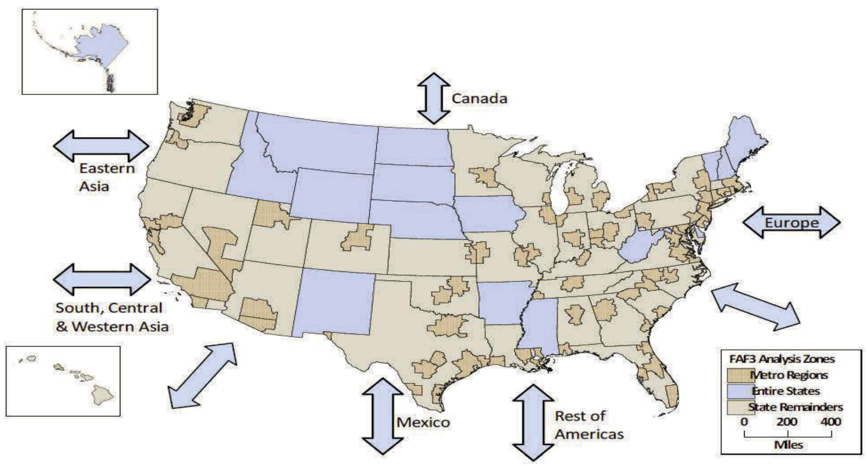
This research effort has identified eight specific methods for corridor evaluation: 1) Tostada, 2) Architecture, 3) 7D Freight Analysis, 4) 7D Built Environment Analysis, 5) Technology Profiling, 6) Walkability Profiling, 7) 7D Scenario Explorer, and 8) Freeway and Arterial corridor throughput analysis. These results should give some indication of how valuable each method may be to your circumstances. The same is true of helping to identify which stakeholder types are the most important to involve – and the more important they are, the more likely you may want to reach out early and even include them in steering committees, etc. Any goals and associated metrics that were heavily triggered suggest a need for a deeper dive into the particulars of those goals and metrics. Data sources that are highly triggered may be useful to research further how they may be able to help further analysis of the corridor.

8.8.1 Enhancements That May Be Developed Soon

Proposal for Commodity Flow Data for Corridor Analysis

The Freight Analysis Framework (FAF) is a commodity flow data product provided by the Federal Highway Administration (FHWA) and Bureau of Transportation Statistics (BTS). A fifth generation of the product (FAF-5) was released in March 2021. One of the first challenges of using FAF data for corridor analysis is its lack of geographic detail. The FAF-5 release maintains the "FAF Zone" geography used in the previous version which includes 132 domestic regions (see Exhibit 1). There are a dozen FAF Zones that encompass an entire state (AK, AR, ID, IA, ME, MS, MT, NM, ND, SD, UT, WY). To examine freight data at a corridor level requires commodity flow data at a more discrete level of geographies, such as a county or MSA. There are over 3,000 counties in the US, and 392 MSAs. While the effort to provide a county-level FAF data set is beyond the scope of the current study effort, it has been proposed to provide the FAF-5 data for MSA geographies and non-MSA counties grouped as remaining areas of a state. The proposed data set will create an origin/destination matrix that is 442 x 442.

FAF Domestic and International Analysis Regions



The proposed FAF-5 by MSA database will express flows by mode in tons and in value by surface modes truck, rail, and inland water, between 442 regions of the nation. The 43 FAF commodity groups will be combined into seven broad categories as shown in the table below:

Code	Commodity Description
1	**Advanced**
1	Live animals and live fish
21	Pharmaceutical products
38	Precision instruments and apparatus
2	**Consumer Goods**
8	Alcoholic beverages
9	Tobacco products
27	Pulp, newsprint, paper, and paperboard
28	Paper or paperboard articles
29	Printed products
43	Mixed freight
3	**Dry Bulk**
2	Cereal grains
3	Other agricultural products
6	Milled grain products and preparations, bakery products
10	Monumental or building stone
11	Natural sands
12	Gravel and crushed stone
13	Nonmetallic minerals n.e.c.
14	Metallic ores and concentrates
15	Coal
4	**Dry/Liquid Bulk**
4	Animal feed and products of animal origin, n.e.c.
22	Fertilizers
23	Chemical products and preparations, n.e.c.*
24	Plastics and rubber

7	Other prepared foodstuffs and fats and oils
5	**Heavy Manufacturing**
25	Logs and other wood in the rough
26	Wood products
31	Nonmetallic mineral products
32	Base metal in primary or semi-finished forms and in finished basic shapes
33	Articles of base metal
41	Waste and scrap
6	**Light Manufacturing**
30	Textiles, leather, and articles of textiles or leather
5	Meat, fish, seafood, and their preparations
34	Machinery
35	Electronic and other electrical equipment, components & office equipment
36	Motorized and other vehicles (including parts)
37	Transportation equipment, n.e.c.*
39	Furniture, lamps, lighting fittings, and illuminated signs
40	Miscellaneous manufactured products
7	**Liquid Bulk**
16	Crude petroleum
17	Gasoline and aviation turbine fuel
18	Fuel oils
19	Coal and petroleum products, n.e.c.* (includes Natural gas)
20	Basic chemicals

The primary independent variable for disaggregating product flows will be county level employment data.

Appendix 9
Corridor Innovation Database Interactive File (xls)

The interactive Corridor Innovation Database is available on the National Academies Press website (nap.nationalacademies.org) by searching for *NCHRP Web-Only Document 386: Quantifying the Impacts of Corridor Management*.

Appendix 10
7-D Calculator Interactive File (xls)

The interactive 7-D Corridor Impact Calculator is available on the National Academies Press website (nap.nationalacademies.org) by searching for *NCHRP Web-Only Document 386: Quantifying the Impacts of Corridor Management*.

Appendix 11
7-D Calculator Methods

Impact on Communities: 7D Framework and Methods for Assessing the Built Environment

The seven D-variables that have developed over time are listed and described in this section based on Ewing and Cervero's

11.1 Methodology

This research project sought to investigate the travel outcomes of corridor impact areas that could be captured as an internal trip (i.e., a trip that originates and terminates within the same corridor impact area) and their mode share of walking, transit use, automobile use, and vehicle miles traveled (VMT). In this regard, the corridor impact area was first defined to examine the association between corridor highways and built environment characteristics, by creating a 2-mile buffer area distancing from the centerline of the corridor using ArcMap10.7.1.

11.2 Selection of Corridor impact areas

At project onset, the research team defined the boundary of the corridor impact areas in order to calculate the D variables of built environment characteristics. Interstate highways in 29 regions were segmented into corridor lines between interchanges or intersections with other corridors of a similar functional class; additionally, corridors in regions with interchanges less than 2-mile were considered as a single corridor line without segments. To set corridor impact area boundaries, 2-mile buffers distancing each corridor centerline were then created in ArcMap10.7.1 . Funderburg et al.'s (2010) examination of three California counties indicated that 2-mile buffers could be used to examine the association between new highway investments and built environmental change. This buffer serves as a corridor impact area where built environment characteristics in terms of D variables and household travel data can be computed consistently for all regions and modeled to forecast the travel outcomes. The resulting 2-mile buffer shapefile was then used to calculate the D variables and household travel data captured within the corridor impact area, resulting in a quantitative output value that can be used to describe the built environment of the corridor segment buffer area.

11.3 Final sample

A total of 95 Interstate corridors in 29 regions were selected and divided into 448 segments. Table 1 shows the statistics of these segments by region, including their survey year, interstate highway number, number of segments, and area of corridor impact areas (2-mi buffer area).

Table 12 Sample statistics

City, State	Survey year	Interstate highway	Number of segments	Area of Corridor impact area (2-mi buffer area) (sq mi)
Albany, NY	2009	I-87,787	19	466.6
Atlanta, GA	2011	I-20,75,85,285,675	31	1238.4
Boston, MA	2011	I-90,93,95,495	25	1319.9
Dallas, TX	2009	I-20, 30, 35E, 45, 635	18	1208.2
Denver, CO	2010	I-25,70,76,225	9	666.4
Eugene, OR	2009	I-5, 105	3	74.2
Greensboro, NC	2009	I-40, 85	8	281.5
Hampton Roads-Norfolk, VA	2009	I-64,264,564,664	17	671.1
Houston, TX	2008	I-10, 45, 610	16	1042.7
Indianapolis, IN	2009	I-65,69,70,74,465	24	1339.1
Kansas City, MO	2004	I-29,35,123,435,470,635,670	55	1745.6
Madison, WI	2009	I-39,90,64	5	253.2
Miami, FL	2009	I-75, 195, 595	3	110.8
Minneapolis-St. Paul, MN-WI	2010	I-35, 35w, 35e, 94, 394, 494,694	49	1878.2
Orlando, FL	2009	I-4	4	227.9
Palm Beach County, FL	2009	I-95	3	210.9
Phoenix, AZ	2008	I-8,10,17	15	1327.7
Portland, OR	2011	I-5,84,205	8	2875.5
Provo-Orem, UT	2012	I-15	3	193.6
Richmond, VA	2009	I-64,95,195,295	17	641.7
Rochester, NY	2001	I-90,390,490 590	17	611.1
Salem, OR	2010	I-5	29	479.3
Salt Lake City, UT	2012	I-15, 80, 215	6	500.3
San Antonio, TX	2007	I-10, 35, 37, 410	30	954.7
Seattle, WA	2014	I-5, 90,405	10	479.3
Springfield, MA	2011	I-90,91,291,391	12	455.4
Syracuse, NY	2009	I-81, 90, 481, 690	21	564.5
Tampa, FL	2009	I-4, 75, 275	10	531.3
Winston-Salem, NC	2009	I-40	8	268.2
Total		**95**	**448**	**22,190.7**

11.3.1 Description of D variables

The seven D-variables that have developed over time are listed and described in this section based on Ewing and Cervero's work in 2010. The first five D-variables measure characteristics of the built environment and are most commonly used in D-variable analysis. The last two are less commonly used and not directly related to the built environment. They are described here but not used in the methodology presented to analyze the built environment within corridors.

11.3.2 Density

Density, one of the original three Ds, can be measured in multiple ways. One way to measure density is population density, typically expressed in people per square mile, but any similar unit may be substituted. Another measure of density is employment density, or the number of jobs per square mile (again, similar units of measurement would also work). A better, more holistic measure of density when analyzing the overall built environment is activity density, which is defined as the sum of residents and jobs divided by area. Since both residential and commercial areas interact with corridors, activity density is the preferred measure to use in this methodology.

11.3.3 Diversity

Not to be confused with demographic diversity, this variable measures the diversity of land-uses. In travel behavior analyses using D-variables, mixed-use areas typically exhibit lower average VMT than homogenously developed areas. Land-use diversity is quantified using land-use data to classify each parcel's land-use as either residential, commercial, or public. Spatial analysis software is used to determine how much of the analysis area falls into each land-use category, and a simple land-use entropy equation is then used to provide an overall measure of land-use diversity for a given area.

11.3.4 Design

Design, as a D-variable, refers specifically to street network design. In terms of travel behavior, a well-connected street grid (e.g., a downtown street grid) is known to promote active transportation and transit use, while areas with curvilinear, less-connected street networks (e.g., suburban residential street systems) tend to exhibit relatively higher automobile mode shares. In the context of a corridor, connectivity may influence both access to destinations from the corridor and access to the corridor from nearby origins. Spatial analysis software is used to calculate the number of 3-way and 4-way intersections within the analysis area. Two descriptive built environment measures are then calculated: percentage of 4-way intersections (most ideal for connectivity compared to 3-way intersections) and intersection density (total number of intersections per square mile).

11.3.5 Destination Accessibility

This D-variable can be measured in a variety of conceivable ways and is related to the other four built-environment D-variables. The University of Utah's D-variable database contains data on employment accessibility by transit and auto for each traffic analysis zone. Employment accessibility is a decent proxy variable for destination accessibility, as "destinations" are typically locations where people are employed, shop, go to school, and have other trip attractions. Measures of destination accessibility possible to quantify with the Utah database include the number and percent of jobs in the metropolitan area accessible within 10, 20, and 30 minutes by automobile and the number and percentage of jobs in the metropolitan area accessible within 30 minutes by transit.

11.3.6 Distance to Transit

Distance to transit is a variable that quantifies transit accessibility. In previous D-variable studies, areas rich in transit tend to exhibit lower VMT. This variable can be quantified in a variety of ways, including average distance from residences and workplaces to the nearest transit stop, transit route density, distance between transit stops, and transit stop density. In this methodology, transit stop density is used to quantify this variable. It is perhaps the simplest way to quantify distance to transit, as transit stop data is often readily available. Spatial analysis software is used to generate a count of transit stops in an analysis area, and the raw count is standardized by square mile (any other unit of spatial analysis can also work here).

11.3.7 Demographics

The demographics variables are just as they sound: data about people. These variables may be included in D-variable analyses whose purpose is to predict travel behaviors in a given area, as demographic information such as median household income, household size, vehicles per household, etc., may influence VMT, mode choice, and other travel behaviors.

11.3.8 Demand Management

Demand management is a D-variable not always included in D-variable analyses, while the first five D-variables are generally considered standard. Very few D-variable studies include demand management as a measurable variable. Demand management is typically thought to include parking supply and cost. This data, particularly parking supply, is not readily available in any public dataset and requires in-person parking counts. Because of the labor involved in collecting this data, this D-variable is best left to D-variable analysis for specific development sites, such as TODs.

This methodology will not include demand management due to the inherent difficulty in collecting parking count and price data along entire corridor segments. Additionally, the writing of this document coincides temporally with the COVID-19 pandemic, and traveling to Houston or other regions in the sample to conduct field observations of parking is not possible due to institutional travel restraints. However, in theory, demand management can be quantified by using parking data collected in the field to estimate the average cost of parking in a study area.

11.4 D variables calculation

The University of Utah's database is capable of producing data for the following D-variables: density, diversity, design, destination accessibility, and distance to transit. For density, the ArcGIS model outputs data on the number of jobs and people in each buffer area (separate measurements). Activity density is calculated as follows:

$$Activity\ density = \frac{residents + jobs}{sq.mi.}$$

For diversity, the Utah model outputs the area of land devoted to each of three categories: residential, commercial, and public. In Excel, calculate the proportion of each corridor buffer used for each land-use type. Then, use the following equation to calculate land-use entropy according to Ewing et al. (2015):

$$entropy = -\frac{residential\ share * \ln(residential\ share) + commercial\ share * \ln(commercial\ share) + public\ share * \ln(public\ share)}{\ln(3)}$$

There is also a measure of job-population balance, another form of diversity. It is calculated as:

Job-population balance =
1 - [ABS(employment - 0.2 * population)/(employment + 0.2 * population)]; ABS is the absolute value of the expression in parentheses. The value 0.2, representing a balance of employment and population, was found through trial and error to maximize the explanatory power of the variable.

For design, the Utah model outputs the number of 3-way intersections and the number of 4-way intersections in each buffer area. The percentage of 4-way intersections and the intersection density is calculated as follows:

$$\%\ 4\ way = \frac{\#\ 4\ way\ intersections}{total\ \#\ intersections}$$

$$Intersection\ density = \frac{total\ \#\ intersections}{sq.mi.}$$

For destination accessibility, the Utah model outputs a TAZ that best represents each individual buffer area and a separate spreadsheet with job accessibility for each TAZ in the metropolitan area. Each buffer area's matching TAZ number is found in the job accessibility spreadsheet, and copy and paste the data for the number and percent of jobs accessible in 10, 20, and 30 minutes by car and number and percent of jobs accessible within 30 minutes by transit.

Finally, for distance to transit, the Utah model produces a count of transit stops in each buffer area. Transit stop density is calculated as follows:

$$transit\ stop\ density = \frac{\#\ transit\ stops}{sq.mi.}$$

Calculation of each D-variable resulted in a quantitative output value that could be used to describe the built environment of the corridor segment buffer area.

11.4.1 Data sources and variables

Based on the final samples selected as corridor impact areas, D variables in terms of built environment characteristics and household travel data with X-Y coordinates were computed for the corridor impact areas, including traffic analysis zones (TAZs). The data with X-Y coordinates were fed into an ArcMap model to produce raw measures of the D variables and provide the attributes' information at the parcel level. These measures were used descriptively on their own, which this methodology does, but they have also been used to model travel behaviors. It provides socioeconomic information, street networks, transit stops, and travel times among TAZs using both automobiles and transit (Tian et al., 2020).

In addition to D variables, regional household travel surveys that collect daily travel diaries of households are widely used to examine household travel behavior. The Metropolitan Planning Organizations (MPOs) across the U.S. use the household travel surveys as the fundamental input for modeling and forecasting regional travel demands. Household travel survey data were obtained via contact with nationwide metropolitan planning organizations in the years between 2010-2020. This particular study required the XY coordinates of the trip ends to identify trips generated by the corridor impact area. Trips are generated in a corridor impact if they either begin and/or end within the corridor. As not every region was willing to share X-Y coordinates due to confidentiality concerns, the investigation was limited to 29 regions. It does not contain every possible data point from which the Ds can be measured.

11.4.2 Variables and description

Table 13 Variables and description

Outcome variables		Definitions
	INTERNAL	Dummy variable indicating that a trip starts and ends internal to the CIA (1=internal, 0=external)
	WALK	Dummy variable indicating that a travel mode on all trips is walking (1=walk, 0=other)
	TRANSIT	Dummy variable indicating that a travel mode on all trips is transit (1=transit, 0=other)
	AUTO	Dummy variable indicating that a travel mode on all trips is automobile (1=automobile, 0=other)
	VMT	Network trip distance between origin and destination locations for a private vehicle trip, in miles
Explanatory variables		
	Level 1. individual/ household level	
Demographics	HHSIZE	Number of members of the household
	VEHCAP	Number of motorized vehicles per person in the household
	Level 2. corridor explanatory variables	
Development scale	AREA	Gross land area of the buffer in square miles
	DEVLAND	Proportion of developed land within the buffer
Density	ACTDEN	Activity density per square mile within the buffer. Sum of population and employment within the buffer, divided by gross land area
	EMPMILE	Total employment outside the buffer within two miles of the boundary. Weighted average for all traffic analysis zones (TAZs) intersecting the

		buffer. Weighing was done by proportion of each TAZ within the buffer boundary relative to an entire TAZ area
Diversity	JOBPOP	Index that measures the balance between employment and resident population within buffer (Index value 0~1)
	LANDMIX	Another diversity index that captures the variety of land-uses within the buffer
Design	INTDEN	Number of intersections per square mile of gross land area within the buffer
	pct4way	Percentage of 4-way intersections within the buffer
	PCTEMP30T	Percentage of total regional employment accessible within 30 min travel time of the buffer using transit
	PCTEMP10A, PCTEMP20A, PCTEMP30A	Percentage of total regional employment accessible within 10, 20, and 30 min travel time of the buffer using an automobile at midday
Distance to transit	STOPDEN	Number of transit stops within the buffer per square mile of land area. Uses 25 ft buffer to catch bus stops on periphery
	Level 3. Regional explanatory variables	
	REGPOP	The population within the region
	GASPRICE	Average state gasoline price for the year of household travel data

11.4.3 Multilevel logistic regressions

Multilevel logistic regression models were used for the statistical analysis because trips (outcome variables) made by individuals are nested within corridors within regions (i.e., three levels). Four multilevel regressions were estimated using HLM 6.08. These statistical models have four travel outcomes: choice of internal trips, choice of walking on all trips, choice of transit on all trips, and vehicle miles traveled (VMT) per trip.

11.5 Results

11.5.1 Descriptive statistics

Table 3 shows the mode share (walk, bike, transit, auto) of all trips, internal capture rate, mode share of internal trips, and average VMT in all 29 regions. Overall mode share of all regions shows the highest percentage in auto trips and declines in the order of walk, transit, and bike. The average automobile mode share for all regions is 77%, which suggests a high percentage of automobile trips are generated within 2-miles from the corridor highways throughout the 29 regions. The internal capture rates differ for each corridor impact area in different regions. Among 29 regions, the average internal capture rates range from a low of 38.9% in Albany, NY, to a high of 65.9 % in Seattle (Table 3). The overall internal capture of all regions is 51.4 %, which has a similar percentage of external trips. In addition, the overall average walking mode share for internal trips is 75.2 %, which means that the dominant mode for internal trips is walking. Table 4 presents the descriptive statistics for all 29 regions by variable.

Table 14 Descriptive statistics for all trips generated within Interstate Highway Corridors within the 29 regions

Region	Mode share for all trips (%)				Internal capture (%)	Mode share for internal trips (%)				VMT
	Walk	Bike	Transit	Auto		Walk	Bike	Transit	Auto	per trip
Albany, NY	10.2	0.4	2.7	86.0	38.9	86.0	0.4	2.7	10.2	103,578
Atlanta, GA	13.2	0.7	6.8	76.2	44.5	76.2	0.7	6.8	13.2	82,266
Boston, MA	30.1	1.5	13.0	53.1	65.2	53.1	1.5	13.0	30.1	35,571
Dallas, TX	8.5	0.2	2.3	88.0	42.9	88.0	0.2	2.3	8.5	92,949
Denver, CO	15.3	1.1	6.0	76.1	56.9	76.1	1.1	6.0	15.3	290,292
Eugene, OR	15.4	5.3	4.1	74.3	60.1	74.3	5.3	4.1	15.4	55,836
Greensboro, NC	4.9	0.2	1.3	92.8	38.9	92.8	0.2	1.3	4.9	75,419
Hampton Roads-Norfolk, VA	7.4	0.5	1.8	90.4	50.1	90.4	0.5	1.8	7.4	204,708
Houston, TX	4.8	0.2	1.9	89.1	44.2	89.1	0.2	1.9	4.8	54,584
Indianapolis, IN	8.7	0.9	3.1	84.8	49.8	84.8	0.9	3.1	8.7	31,585
Kansas City, MO	4.4	0.2	1.7	90.5	41.0	90.5	0.2	1.7	4.4	144,548
Madison, WI	8.3	0.0	0.9	88.3	49.3	88.3	0.0	0.9	8.3	17,062
Miami, FL	16.1	0.4	5.1	75.2	46.7	75.2	0.4	5.1	16.1	87,053
Minneapolis-St. Paul, MN-WI	12.3	2.4	5.2	78.0	45.4	78.0	2.4	5.2	12.3	75,129
Orlando, FL	8.2	0.8	1.9	87.7	49.5	87.7	0.8	1.9	8.2	14,701
Palm Beach County, FL	11.2	0.9	1.8	85.4	61.0	85.4	0.9	1.8	11.2	5,057
Phoenix, AZ	9.6	1.1	1.7	84.8	45.8	84.8	1.1	1.7	9.6	21,952
Portland, OR	28.9	4.3	9.8	55.4	63.1	55.4	4.3	9.8	28.9	20,874
Provo-Orem, UT	7.1	1.1	0.8	90.2	63.7	90.2	1.1	0.8	7.1	27,877
Richmond, VA	11.6	0.9	2.0	84.5	49.8	84.5	0.9	2.0	11.6	14,236
Rochester, NY	5.4	1.4	1.3	91.0	42.3	91.0	1.4	1.3	5.4	7,065
Salem, OR	8.9	1.0	4.4	85.4	51.9	85.4	1.0	4.4	8.9	4,825
Salt Lake City, UT	7.1	1.8	2.4	88.1	56.3	88.1	1.8	2.4	7.1	10,184
San Antonio, TX	4.4	0.3	1.2	91.0	41.1	91.0	0.3	1.2	4.4	21,090
Seattle, WA	26.8	2.7	8.9	57.4	65.9	57.4	2.7	8.9	26.8	35,156
Springfield, MA	16.1	0.9	6.1	76.0	58.6	76.0	0.9	6.1	16.1	26,125
Syracuse, NY	9.4	0.8	2.4	86.3	48.1	86.3	0.8	2.4	9.4	24,928
Tampa, FL	9.4	0.8	1.6	86.9	44.0	86.9	0.8	1.6	9.4	556

Winston-Salem, NC	5.6	0.2	1.6	91.3	48.0	91.3	0.2	1.6	5.6	70,405
Overall	14.0	1.5	5.4	77.0	51.4	75.2	1.6	5.8	15.3	1,655,611

Table 15 Descriptive statistics by variable

		N	Mean	S.D.	Minimum	Maximum
Level 1	INTERNAL	1,479,136	0.51	0.50	0.00	1.00
	WALK	1,478,746	0.13	0.34	0.00	1.00
	TRANSIT	1,478,746	0.05	0.22	0.00	1.00
	VMT	1,470,364	4.74	6.85	0.00	276.89
	LN_HHSIZE*	1,458,197	0.91	0.54	0.00	2.71
	LN_VEHCAP**	1,458,197	0.54	0.25	0.00	2.40
Level 2	LN_ACTDEN	409	1.01	1.37	-8.08	3.43
	LN_JOBPOP	409	-0.85	0.43	-2.33	-0.01
	LN_ENTROPY*	409	0.54	0.10	0.17	0.69
	LN_PCT4WAY	409	3.21	0.47	2.03	4.17
	LN_INTDEN*	409	3.97	0.78	0.77	5.23
	LN_STOPDEN*	409	2.18	1.34	0.00	4.89
	LN_PCTEMP10A	409	1.35	1.89	-6.13	4.36
	LN_PCTEMP20A	409	3.24	1.27	-2.59	4.59
	LN_PCTEMP30A	409	3.93	0.94	-2.59	4.61
	LN_PCTEMP30T*	409	2.57	1.52	0.00	4.61
Level 3	LN_REGPOP	29	14.18	0.94	12.38	15.67
	LN_REGPOPDEN	29	6.52	0.56	5.52	8.27
	LN_GASPRICE	29	1.06	0.04	1.00	1.15

* "LN" at the beginning of each variable represents the natural log version of that variable.
** 1.0 was added to the variable value before it was logged.

11.5.2 Internal trips

Table 16 shows the model results of the multilevel binomial logit regression for internal capture. At the individual level (level 1), the likelihood of a trip being captured internally by a corridor impact area decreases with household size and the number of motorized vehicles per person in the household (VEHCAP). That means a household with more members is less likely to stay within a corridor impact area. In addition, the higher number of motorized vehicles per person in the household, the less likely a trip is internal. At the corridor level (level 2), the internal trips variable is positively associated with two D variables: job population (JOBPOP) and intersection density (INTDEN). The probability of a trip being captured within a corridor impact area increases with the balance between employment and resident population within the buffer and the number of intersections per square mile of gross land area within the buffer.

Table 16 Multilevel binomial logistic regression for internal capture

Variables		*Coef.*	*t-ratio*	*p-value*
	Constant	-0.045	-0.274	0.786
Level 1	LN_HHSIZE	-0.415	-8.613	0.000
	LN_VEHCAP	-1.025	-15.509	0.000
Level 2	LN_JOBPOP	0.192	3.372	0.001
	LN_INTDEN	0.219	5.349	0.000

11.5.3 Mode choice for walking trips

Table 17 shows the model results of the multilevel binomial logit regression for walking on internal trips. At the individual level (level 1), the likelihood of walking trips decreases with household size and vehicle per capita. This means that household size and vehicle per capita negatively impact the probability of choosing walk trips for all trips, both internal and external. At the corridor level (level 2), the probability of walk trips increases in the corridor impact areas with a higher percentage of 4-way intersections within the buffer (PCT4WAY) and a larger number of transit stops within the buffer per square mile (STOPDEN).

Table 17 Multilevel binomial logit regression for walking trips

Variables		*Coef.*	*t-ratio*	*p-value*
	Constant	-4.781	-9.906	0.000
Level 1	LN_HHSIZE	-0.415	-4.099	0.000
	LN_VEHCAP	-1.714	-5.954	0.000
Level 2	LN_PCT4WAY	1.088	8.765	0.000
	LN_STOPDEN	0.106	2.539	0.012

11.5.4 Mode choice for transit trips

In Table 18, the model results of the multilevel binomial logit regression for transit mode choice are shown. At the individual level (level 1), the mode choice of transit use for all trips decreases with household size and the number of vehicles per capita. At the corridor level (level 2), the choice of transit is positively correlated with the percentage of 4-way intersections and the number of transit stops per sq. mile.

Table 18 Multilevel binomial logit regression for transit trips

Variables		*Coef.*	*t-ratio*	*p-value*
	Constant	-5.225539	-4.884	0.000
Level 1	LN_HHSIZE	-0.456987	-3.203	0.002
	LN_VEHCAP	-2.374842	-4.261	0.000
Level 2	LN_PCT4WAY	0.881575	3.159	0.002
	LN_STOPDEN	0.174033	1.980	0.048

11.5.5 Vehicle miles traveled (VMT)

Table 19 shows the results of the multilevel regression model for vehicle miles traveled (VMT) in corridor impact areas. At the household level, household size and vehicles per capita have positive associations with VMT. At the corridor level, activity density per square mile within the buffer (ACTDEN) and the balance between employment and resident population within the buffer (JOBPOP) have negative effects on VMT. In other words, higher activity density and job-population balance will lead to lower VMT.

Table 19 Multilevel regression for Vehicle miles traveled (VMT)

Variables		*Coef.*	*t-ratio*	*p-value*
	Constant	1.760	1.469	0.153
Level 1	LN_HHSIZE	1.218	7.755	0.002
	LN_VEHCAP	4.729	15.994	0.000
Level 2	LN_ACTDEN	-1.474	-4.374	0.000
	LN_JOBPOP	-1.992	-4.316	0.000

11.6 Conclusion

This analysis aims to provide new performance measures for highway corridors that can quantify the impact of coordination between transportation corridors and land-use. There have been few attempts to quantify the impact either in planning practice or academia. While the conventional corridor management strategies used by MPOs have primarily centered on expanding roadways and reducing congestion to maintain a free flow of traffic, they have ignored the interactions between transportation corridors and the areas they serve. These cannot be complete solutions to underlying traffic problems.

The approach used in this analysis is the first attempt to quantify the interaction between the corridor and surrounding land-use by measuring the built environment characteristics of corridor impact areas and household travel patterns.

In this study, four different models were estimated: internal trips, walking trips, transit trips, and vehicle miles traveled (VMT). Note that the models only consist of predictors that are significant at 0.05 level. Unsurprisingly, none of the regional variables were significant in the models. This is mainly due to the small sample size (29 regions), resulting in less statistical power at level 3. The results indicate that the D variables of the built environment at the corridor level matter.

More specifically, the likelihood of internal trips decreases with household size and number of motorized vehicles per person in the household. The probability of a trip being captured within a corridor impact area increases with the balance between employment and resident population and the number of intersections per square mile within the two-mile buffer around the highway section (level 2). The walk choice model indicates that the likelihood of having walk trips is negatively correlated with household size and vehicles per capita. At the corridor level (level 2), the corridor impact areas with a higher percentage of 4-way intersections and a greater number of transit stops per square mile increase the probability of walk trips. In terms of transit mode choice, it decreases with household size and the number of vehicles per capita at the household level. At the corridor level (level 2), transit use is positively correlated with the percentage of 4-way intersections and with transit stop density. As for the VMT model, VMT is positively associated with household size and vehicles per capita and negatively correlated with activity density and job-population balance within the buffer.

In conclusion, when it comes to measuring corridor performance, planners should consider the land-use characteristics surrounding corridor highways, especially job-population balance, intersection density, transit stop density, and percentage of 4-way intersections within the corridor impact areas. Furthermore, at the household level, the number of household members and the number of vehicles per person in a household are primary factors that have significant impacts on the corridor performance.

Appendix 12
Spatial Environment

This document provides a **guiding framework** for State Departments of Transportation (DOT) to use in establishing the geospatial environment for quantifying corridor management impact metrics. The framework describes processes for computational application of methods and tools that a DOT could use to understand how well corridor management methods are working. This framework is based on existing methodologies and tools detailed in this document and how to adapt data to them in order to do spatial analysis. This framework serves to assist DOTs in thinking about their capabilities and how to use these approaches to meet their needs.

This framework has been structured to:

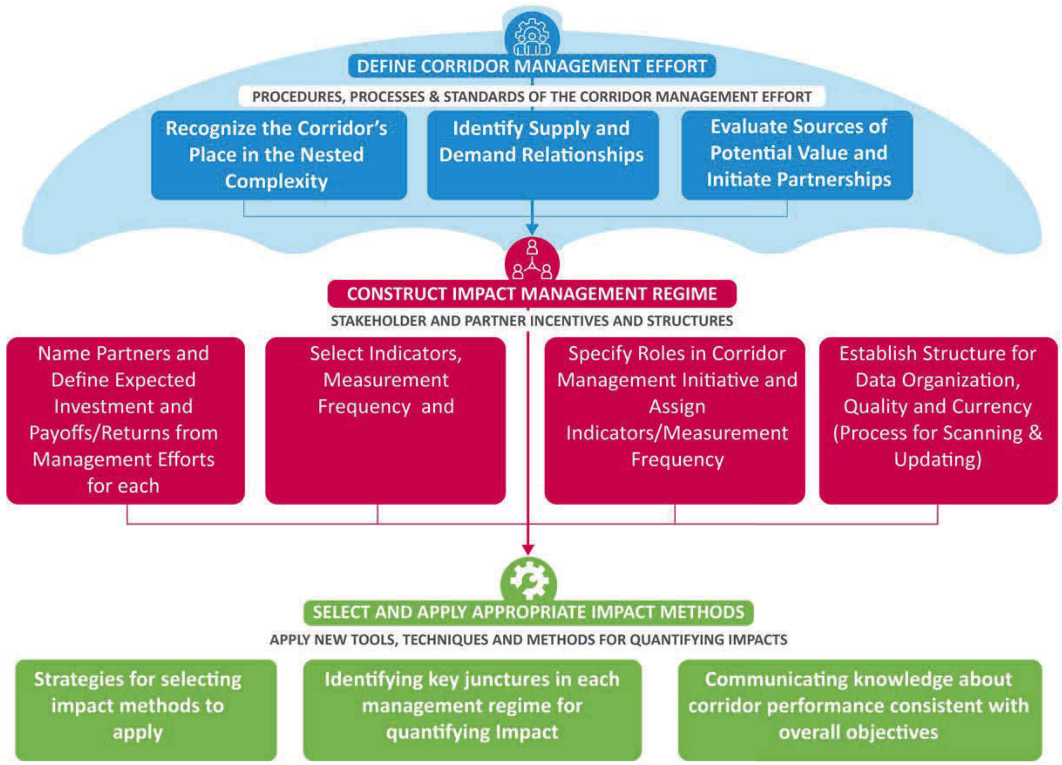
1. Address the key resources needed for establishing a spatial corridor impact computing environment at a State DOT;
2. Describe the steps for creating the geospatial environment, its data inputs, and methodology; and
3. Recommend practices for reporting corridor impacts derived in a geospatial computing environment, identifying expected uses/applications of corridor impact results/reports, and delivering advice on how to maintain and use the spatial analysis environment once in place.

The main focus of this framework is how to use geospatial analysis considering a corridor where there is a key roadway and it is possible to conflate data to highway network. However, as not all data are aligned to highway corridors, this framework provides some recommendations for conflating regional or non-highway-based data to a highway network or considering broader geospatial analysis. Further, some corridors are focused on bicycle or pedestrian movement, or maybe they are multimodal corridors. This framework can incorporate ratings or scores for multimodal connections, but again, the priority for this framework is roadway-based corridor management impact analysis. To the extent connections can be made for other modes, the guidance reflects that.

12.1 Background

Play 4: Build a Spatial Analysis Environment addresses developing the spatial environment for corridor management. Appendix 5.3 describes one popular methodology for integrating multiple aspects of performance into a spatial corridor analysis. This appendix elaborates on the execution of TOSTADA using resources available in a typical coalition or transportation agency context. Figure 23 (first introduced in Play 1: Define the Corridor and Its Impact and also elaborated in Appendix 5.1) illustrates programmatic steps of corridor management. The creation of the spatial environment occurs in the selection and application of appropriate impact methods (shown in green).

Figure 24. NCHRP 08-124 Original Framework



This framework was intended to provide guidance for State DOTs, regional, and local transportation, and land-use planning agencies who coordinate development planning and infrastructure investment in multimodal passenger and freight transportation networks. It was determined that a framework with specific strategic approaches to measuring impacts (quantitatively and qualitatively) using spatial analysis would benefit state DOTs. Thus, a guiding framework is needed to help practitioners at DOTs and planning agencies determine whether and how to create a spatial environment for quantifying corridor impacts. This document is intended to serve as the guiding framework for implementing a corridor management program. It was vetted with select DOTs to ensure that the guidance was appropriate and applicable by a DOT.

12.2 Why Establish Spatial Corridor Management Impact Analysis

There are numerous practical reasons for pursuing spatial analysis to understand corridor management impacts. One of the most critical is that spatial analysis is visual and helps agencies and stakeholders see what conditions look like prior to any corridor management efforts, as well as after completion of projects. This visualization goes a long way in communicating with stakeholders and in being able to analyze what is working, what is not working, where it may or may not be working, and how well it is working.

Spatial analytics are beneficial to planners and decision-makers at transportation agencies seeking to understand where to apply or adjust corridor management efforts. In particular, geospatial corridor analysis provides the ability to:

- Find candidate project locations and communicate benefits in ways that best reach stakeholders in a visual manner.
- Score potential projects across condition and performance outcomes for the same geographic area.
- Calculate economic benefits and benefit-cost (B/C) ratios and map them for stakeholders to see where benefits are greatest.
- Visualize or display before and after results in an illustrative manner.
- Study future investment and travel demand option scenarios and demonstrate them visually.
- Pinpoint problems to attack through potential projects by using existing mapped databases that identify locations with multiple deficiencies (e.g., pavement, bridge, congestion, safety) or opportunities (high freight value, developer interests).

12.3 Key Steps Needed to Establish a Spatial Corridor Impact Computing Environment

Establishing a spatial environment for quantifying corridor management impacts may be useful for a transportation planner looking to:

- Understand base-level, existing conditions of a corridor's performance;
- Plan and prioritize investments in capital, operations treatments (e.g., Transportation System Management and Operations [TSMO]), and maintenance projects in accordance with corridor needs;
- Visualize and assess impacts of corridor management plan implementation; and
- Measure and evaluate the impacts of maintenance, operations, and capital projects on corridor performance.

Therefore, spatial analysis could help with identifying needs at the outset of a corridor management planning effort, such as pavement rehabilitation, bridge rehabilitation or reconstruction, congestion mitigation, environmental quality, safety improvements, and potential for economic and community development. Spatial analysis could also be used as a "rearview mirror" to determine the effectiveness of corridor management treatments or plans after completion. Whether the spatial corridor environment is needed at the outset of planning or after project or plan completion, the method for creating it can generally be summarized in six steps:

1. Determine the geographic area of interest for spatial corridor impact analysis.
2. Identify the skills and tools available for spatial corridor impact analysis.
3. Assess the data available for spatial corridor impact analysis.
4. Select the most important performance goals for corridor management.
5. Understand spatial corridor impact analysis measurement tools or programs available.
6. Quantify corridor impacts using a spatial corridor impact analysis tool, program, or resource.

The six steps are described below.

12.3.1 Step One: Determine the Geographic Area of Interest for Spatial Corridor Impact Analysis

A typical State DOT or other transportation planning agency may have more problematic corridors than they have resources to target for planning studies or capital improvements. In addition, one regional corridor (e.g., an interstate like I-95 on the East Coast or I-5 on the West Coast) may have multiple problematic segments that must compete for the same State, regional, or local resources. Thus, it is important to narrow corridor analysis to a geographic area of interest for which: (a) funding and stakeholder interest are available to justify the investment; (b) a corridor has the potential to serve a specific transportation purpose but cannot due to existing conditions; and (c) data are available and regularly updated.

Narrow Corridor Analysis to an Area with Sufficient Funding and Stakeholder Interest

The geographic limits of spatial corridor impact analysis will have to pragmatically be set by the available funding for a corridor plan or project from a given agency that manages the corridor. The agency could be a State DOT, metropolitan planning organization (MPO), or local transportation or public works agency with jurisdiction over the corridor of interest. A financial investment may be necessary to undertake the spatial corridor impact analysis. The allocation of funding for the corridor analysis will be more easily justified if the corridor is located where elected officials, their constituents, or other influential stakeholders have raised concerns and are seeking solutions.

Narrow Corridor Analysis to a Corridor That Cannot Serve an Intended Purpose Due to Existing Conditions

Each corridor management effort should define the extent of their management activity and the scope of impact of interest. These definitions may include areas within the right-of-way of the facility, as well as street systems, transit lines, neighborhoods, local economies, or supply chains of concern to key stakeholders. In other words, a corridor may be defined by geography, as well as by transportation function and problematic transportation conditions.

As an example, a corridor may contain a heavily congested Interstate as well as an under-developed and underserved freight rail infrastructure. The Interstate not only wastes time and money for commuters, but also for freight movement. Spatial corridor impact analysis may be useful at the outset of project planning to determine the extent to which freight moving primarily by truck is delaying commuters and trucks, deteriorating pavement and bridges, and increasing the risk of crashes. A corridor management strategy may be implemented to relieve traffic by moving freight from truck to rail. Spatial corridor impact analysis may be useful during project planning to quantify and compare the potential benefits of alternatives, such as development of an intermodal facility, inland port, or other railroad infrastructure. After project completion, it could also be used to assess whether the preferred alternative is addressing traffic as planned. In this way, the corridor, while focused on the congested segment of Interstate, includes nearby freight railroad infrastructure and developable land, and serves a freight transportation purpose.

Spatial corridor impact analysis is useful at various stages of project planning and development to identify and evaluate problematic transportation conditions. These conditions may need to be viewed together in a spatial environment for transparent, consistent, and effective decision-making.

Narrow Corridor Analysis to an Area Where Data Are Available

State DOTs and other transportation planning agencies may also find it useful to define a corridor in terms of the data that are available and regularly updated. For example, federal sources, such as the Highway Performance Monitoring System (HPMS), All Roads Network Of Linear Referenced Data (ARNOLD) layer, and National Performance Management Research Data Set (NPMRDS), provide volume, pavement condition, and speed data for the Traffic Message Channel (TMC) network, a map of the nation's roads split into smaller segments (known as TMCs) based on industry agreement. A corridor could be defined as a TMC or series of TMC segments, for which HPMS and NPMRDS data are available and up to date at no cost to the user. In this way, a State DOT or other transportation planning agency undertaking spatial corridor impact analysis will have an easy, convenient, and credible way to assess a corridor's condition or performance without having to pay for data or create their own means of acquiring data.

Another element here is to consider the buffer of the corridor and the catchment area. This means that when identifying the corridor, it is important to look at the roadway network and also the ½-mile to 1-mile buffer in the corridor in terms of measuring the performance. Additionally, having a catchment area or understanding that there are impacts at certain distance bands from the corridor helps to connect the corridor to other geographies.

12.3.2 Step Two: Identify the Skills and Tools Available for Spatial Corridor Impact Analysis

State DOTs and regional and local transportation planning agencies vary in their in-house and procured technical skills and the technological tools available to them. This may depend on available budget, the local talent pool, access to consultants with spatial corridor analysis expertise, and culture of the agency. Thus, each agency must identify for itself the skills and tools they currently have to conduct spatial analysis of corridor impacts.

An agency with fewer resources may need to resort to free or "off-the-shelf" tools or software that their planners already access and use with relative ease. These agencies could leverage in-house personnel and expertise they may already have or will develop using tools available at no cost to the agency. Their spatial corridor analyses could benefit from web-based tools that use sources like HPMS or NPMRDS, such as the Federal Highway Administration's (FHWA) Freight Mobility Trends (FMT) tool, which provides performance data related to delays due to congestion on those segments. They may also use other no-cost tools, such as Google Earth, or analyze data using Microsoft Excel, which they may already have access to for other purposes.

Agencies could also take advantage of visualization, analytical, and mapping tools such as Tableau, the Regional Integrated Transportation Information System (RITIS), and ArcGIS Online. Agencies with a greater depth of in-house analytical skills and tools, as well as a culture of innovation, may be equipped to undertake spatial corridor impact analysis that takes advantage of customizable tools they can purchase or develops their own tools. Texas, for example, has several custom resources that they can use, such as the Congestion Management and Analysis Tool (COMPAT) and Truck Congestion Analysis Tool (T-CAT) along with multiple geospatial options. Maryland is another state with significant geospatial options and emerging custom tools, such as the Maryland Roadway Performance Tool (MRPT).

Table 20provides a typology of personnel, skills, and technological and other tools that agencies with low, medium, and high levels of resources may possess to create spatial environments for quantifying corridor impacts. The data available to agencies to conduct spatial corridor impact analysis (under Step Three), the performance goals for corridor management (under Step Four), and the spatial corridor impact analysis measurement tool they ultimately use (under Step Five) will be determined by whether they are a low, medium, or highly resourced agency.

Table 20. Personnel, Skills, and Tools Available to Low, Medium, and Highly Resourced Agencies

		Personnel	Skills	Technological Tools	Other Resources and Data
Resources Available to Agencies	Low	• In-house planning staff	• Internet search	• Google Earth • FHWA FMT • Microsoft Excel	• Collected anecdotal reports, observations, public tool outputs • Basic HPMS data for roadways, asset conditions, and safety • FHWA ARNOLD networks
	Medium	• In-house planning staff • Local consultants	• GIS • Excel modeling • Tableau	• ArcGIS online • Microsoft Excel • Tableau • FHWA FMT • RITIS	• Collected anecdotal reports, observations, and public tool outputs • Basic HPMS and ARNOLD • Mobility, safety, asset condition, and environmental data
	High	• In-house planning and project management staff • Higher-end consultants	• GIS • Excel modeling • Tableau • Software development	• ArcGIS online • Microsoft Excel • Tableau • FHWA FMT • RITIS • Custom tools	• Collected anecdotal reports, observations, and public tool outputs • Basic HPMS and ARNOLD • Mobility, safety, asset condition, and environmental data • In-house tool development (e.g., COMPAT, TCAT, and MRPT)

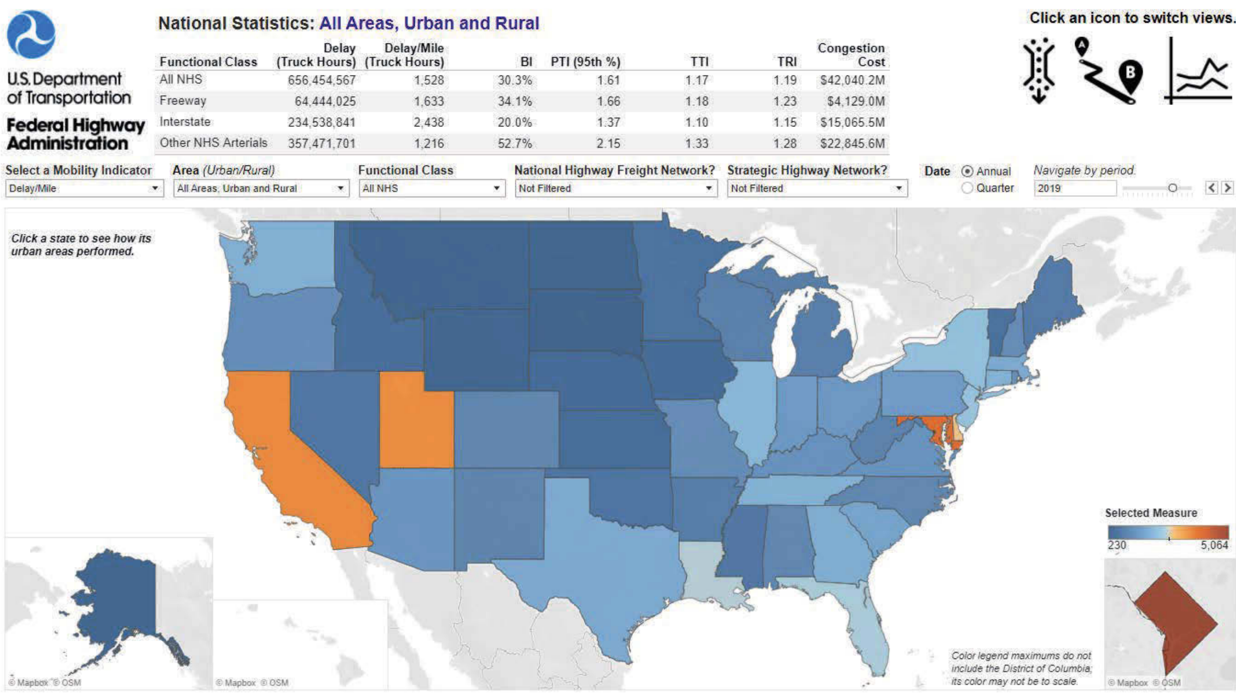
12.3.3 Step Three: Assess the Data Available for Spatial Corridor Impact Analysis

Creating a spatial environment for corridor analysis will require data for that corridor. The data can come from in-house sources, such as extent, condition, performance, use, and operating characteristics of roadways, which State DOTs submit to HPMS to FHWA. It could also come from tools that use data from HPMS or other resources.

It is important to consider the goal, geography, agency capacity, and capabilities to manage and analyze data, free versus costly data, and if there are existing resources that can provide the data that is needed.

For example, FHWA provides the FMT tool for freight-focused analysis nationwide. It is useful for DOTs and MPOs that want to see freight bottlenecks on the National Highway System (NHS), Strategic Highway Network (STRAHNET), or National Highway Freight Network (NHFN). It can be used for a variety of geographic levels. The advantage of using a tool like the FMT (Figure 25) is that it allows a novice or non-technical user from a low-resourced agency to attain mobility and other data without having to know how to calculate performance measures. The FMT also provides data for multiple years, allowing the user to perform simple trends analysis for a given roadway segment or set of segments.

Figure 25. FMT Tool Page (as of February 9, 2021)



While the FMT's three interactive dashboards provide national, State, and urban area freight statistics, a ranked list of freight bottlenecks nationally or by state, and a corridor level indicator of performance and visualization, it is limited to the NHS. The tool was designed for national, high-level views of freight performance and does not offer users granularity or local roadways they may wish to see. However, it can be used to see bottlenecks and understand urban, rural, and functional class type performance for major corridors and regions.

Medium and highly resourced agencies could take advantage of data that they may collect in the normal course of business. Commonly collected data that could be used to conduct a spatial analysis includes (but is not limited to):

- **Mobility** – State DOTs and other transportation planning agencies regularly collect data related to traffic congestion, traffic volumes, and speeds. The performance measures they track could be as simple as level of service and average annual daily traffic, or more complicated measures such as travel time index (TTI) or delay per mile (DPM). TTI is the ratio of the travel time during the peak period to the time required to make the same trip at free-flow speeds, while DPM is weighted by vehicle volumes and normalized by mile. Agencies could also go further, measuring congestion costs that provide an indication of the costliest segments along a corridor based on hours of delay.

- **Safety** – Transportation and law enforcement agencies, as well as the National Highway Traffic Safety Administration (NHTSA), provide and update safety data related to roadways. NHTSA's Fatality Analysis Reporting System (FARS) could be used by a corridor management agency looking to target locations where fatal traffic crashes occur. They could also look to FARS safety data to target locations with higher numbers of overall crashes, as well as where both injury and fatal crashes occur, where certain types of crashes (e.g., property damage only [PDO], angle, and rear end) take place, and where crashes are due to specific causes (e.g., speeding, driving under the influence).
- **Asset Condition** – Pavement condition data are available from State DOTs, which provide grading scale and International Roughness Index (IRI) data for pavement and ride quality of Federal-aid highways to HPMS. Sections of pavement in good condition are rated "good" for three relevant distresses (ride quality, cracking, and rutting for asphalt pavements; ride quality, cracking, and faulting for concrete pavements). Sections of pavement in "poor" condition are rated "poor" for at least two of the relevant distresses. Any pavements not rated as "good" or "poor" are classified as "fair". Because IRI is based on centerline miles and does not provide information on the number or width of roadway lanes, there is a limitation to using the data in corridor analysis. Bridge condition data can be ascertained from FHWA's National Bridge Inventory (NBI). The 2019 edition of the NBI is a database of 628,207 bridges on the NHS containing data submitted by State DOTs based on National Bridge Inspection Standards (NBIS) for the proper and uniform inspection and evaluation of highway bridges. Bridge culverts, substructures, superstructures, and decks are rated in "good", "fair", and "poor" condition. If any one of the four structural items is rated "poor", the bridge is classified as "poor". A bridge is classified as "good" only if all metrics are rated as "good".
- **Environmental** – Air and water quality data can be collected from tools available at the U.S. Environmental Protection Agency's (EPA) website. Its AirData website gives users access to air quality data collected at outdoor monitors across the U.S., Puerto Rico, and the U.S. Virgin Islands. It provides for download monitored hourly, daily, and annual concentration data, air quality index data, and speciated particle pollution data. EPA's National Stormwater Calculator (SWC) allows users to estimate the annual amount of rainwater and frequency of runoff from a specific site using green infrastructure as low-impact development controls. It is designed for use by anyone interested in reducing runoff from a property, including planners. EPA also offers greenhouse gas (GHG) emissions data through its MOtor Vehicle Emission Simulator (MOVES) model. MOVES estimates GHG emissions for mobile sources (cars, trucks and buses, and nonroad equipment such as bulldozers and lawnmowers) at the national, county, and project level for criteria air pollutants, greenhouse gases, and air toxics. Emissions from on-road sources can be modeled at the detailed "project" scale if the user supplies detailed inputs describing project parameters.

A Note on Data Conflation

Much of the data above is conflated to the roadway network or can be conflated because it is already aligned to the roadway. Data such as asset conditions capture in a state's HPMS data program will be aligned to the state's roadway network. Mobility data such as probes for cars and trucks will likely be aligned to the TMC network but can be matched to the HPMS network. This can be difficult, but most states have HPMS staff who can help with this. It is important to line up the networks and develop segmentation so that all the data can be referenced to one specific segment. Many states will create logical segments with their roadway networks meaning they create segments that are between interchanges or key intersections. This way, when assessing performance, they can very easily identify which segments are performing worse than others and focus in on the performance aspect such as pavement deterioration reported in HMPS, or congestion identified from performance measures using the probe data.

Often, there is a need to conflate data to the HPMS network for analysis that is not already linear roadway data. For example, environmental data showing likelihood of flooding or demographic data are not aligned to a roadway network. In these cases, it is important to develop a score that can be tied to the segment. For example, suppose high flooding areas area coded as a 3 while low flooding areas are a 1. Segments in high-flooding areas are coded as a 3 and segments in low-flooding areas are a 1. This could be done with subjects like truck parking. Areas of low truck parking availability could be a 3 while underutilized areas a 1. It is important that whatever coding scheme is developed, that the methodology is clear, and indicators increase or decrease in severity in the same direction as other performance measure scores. For example, it goes from best to worst or worst to best so that any math done to combine scores for segments is correct and helps to reveal segments with the most problems

- **Economic Value** – While transportation agencies typically do not regularly collect and track economic development and land value data, they could have access to economic value tools and data from sister agencies and regional planning bodies (e.g., MPOs). The value of this data to a transportation agency lies in how economic development potential and land values change after corridor improvements are made, especially if the corridor management goal is economic development. The economic value of a corridor can be measured through a simple calculation such as using a ratio of metropolitan to provide Gross Domestic Product (GDP).
- **Freight Value** – The dollar value of truck commodities carried on road segments may be useful if the corridor management goal is the facilitation of freight movement. Freight value data can be estimated using a combination of national and state sources. Truck volumes and the FHWA's Freight Analysis Framework (FAF) can be used to estimate freight value in a region or state for the corridor. Using these truck volume data and FAF information, agencies can develop an annual truck commodity value.

Other types of data may be available and useful for spatial analysis of corridor impacts, but the six detailed categories above represent data that medium and highly resourced transportation agencies generally track in their performance programs. They are relatively readily available and beneficial for assessing base conditions, impacts, and investments, and can be represented on a map or series of maps. For medium and highly resourced transportation agencies with geographic information system (GIS) capabilities in-house or through consultants, it may be useful to process the data into GIS to provide consistent information on topics of interest in one view. They may also need access to resources that can conflate data to the highway network segments for a given corridor, and index, weight, and visualize results in color-coded data maps.

12.3.4 Step Four: Select the Most Important Performance Goals for Corridor Management

Having identified the data available for spatial corridor impact analysis, specific performance goals need to be selected for the corridor management effort. These goals may come from the purpose and need of corridor improvement projects or plans. They could also be generated from the desired performance outcomes of the corridor project or plan that are deemed most important in project or planning documents. An agency with a strategic plan should use key performance indicators (KPIs) provided within it, which have been prioritized based on the corridor management effort and potential positive impact on corridor management goals.

Corridor projects or plans could provide performance goals that can be measured through spatial impact analysis, including:

- Reducing delay caused by traffic congestion;
- Reducing fatal and injury crashes;
- Bringing assets to a state-of-good-repair;
- Mitigating air or water quality and GHG emissions impacts from mobile sources;
- Encouraging economic development through improved highway and transit access to land targeted for development;
- Facilitating active transportation through pedestrian and bicycling improvements; and
- Enhancing the value of freight movement through development of a freight hub, intermodal facility, truck parking, and other improvements.

Note that performance goals should be specific and measurable, and tied to available data. In addition, it is important to keep in mind that a project or plan will serve multiple performance goals. Spatial corridor analysis will provide an assessment of diverse, and sometimes competing needs. A roadway safety project, for example, may also provide improvements in congestion, bridge and pavement condition, and the value of freight moved.

12.3.5 Step Five: Understand Spatial Corridor Impact Analysis Measurement Tools

Spatial analysis usually involves some use of tools that can put information in a map form. Specific measurement tools are available to assess existing corridor performance and evaluate the potential impacts of corridor management strategies. Some tools hold promise as spatial analysis tools singularly displaying an array of impact metrics, while others apply the measures together for a strategically balanced view of corridor impacts. Some tools quantify impacts using available economic and other performance models and methods (e.g., benefit-cost analysis and economic impact models such as REMI and TREDIS), while others utilize multi-criteria indexes that combine and weight different types of impacts.

As in Table 1, the simplest tools available are those that are provided already such as the FHWA FMT tool or RITIS, and others that compute measures easily. However, those resources do not provide the capability for states to combine data or see data all together in a way that helps to prioritize segments or see comprehensive performance.

States with more capability in spatial analysis may have access to tools like Tableau or GIS where data can be manipulated in database tools as simple as Excel and then visualized. Some states that are more advanced have developed their own visualization tools. Texas, for example, has developed the COMPAT and T-CAT tools referenced above, and Maryland has the MRPT tool.

Therefore, it is important to consider what is available and what level of capability a state has for spatial analysis. Depending on how well-resourced an agency is and the needs of the agency, one or a set of these tools could be used as part of a menu of options. While one tool can provide robust information about the corridor's performance, it can also be used as one part of a set of complementary resources that can provide additional decision-making context.

For the overall NCHRP 08-124 research, the following three tools were identified as important resources that can support corridor management projects and planning efforts in setting up the appropriate, relevant measurements:

1. The TOol using STAcked DAta (TOSTADA)
2. Profiling
3. 7-D Analysis

These tools are three examples of how different types of data can be put together to develop some output or score that helps to indicate performance of a corridor. They combine data rather than look at each data stream differently. For example, they use inputs of pavement, congestion, safety, and economics and combine these to create scores for a corridor, some at the segment level, that a transportation planner can use to pinpoint performance issues and to see how corridor management practices have changed performance.

Of these tools, however, TOSTADA is spatial and relies on using spatial resources like ArcGIS, Tableau, SAS, and other database software, even Excel, to develop results. Additionally, using the TOSTADA approach, a state DOT can take results from profiling or 7-D and conflate them to highway segments so that this information can be folded into the TOSTADA analysis and presented visually in a comprehensive score for decision-makers. More on each of these resources is below.

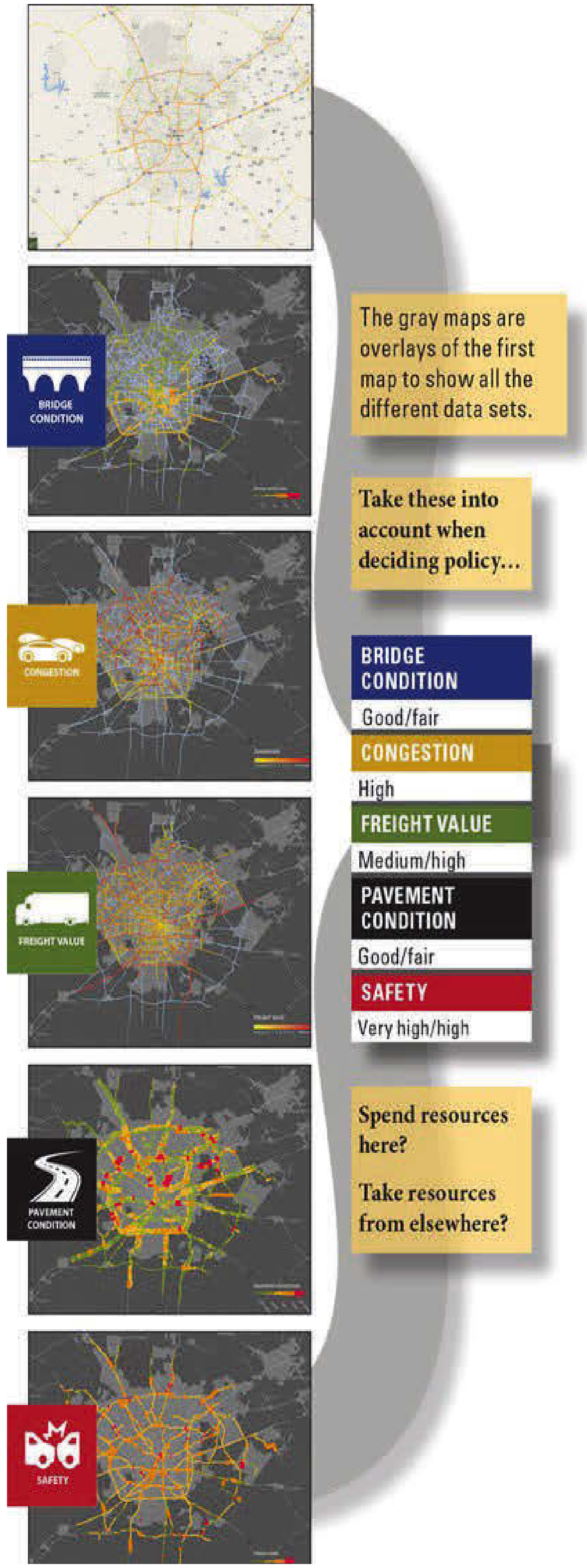
12.4 The TOol using STAcked DAta (TOSTADA)

Developed by the Texas A&M Transportation Institute (TTI), TOSTADA visualizes and prioritizes corridor performance based on aggregated data by highway segment (see Figure 7)[198] Named for the regional dish that layers ingredients, TOSTADA layers datasets to understand performance in a combined way instead of considering each performance area separately. TOSTADA stacked data reporting provides a combined metric, a BITE (Basic InTEgration) that generates one score for performance that provides an indication of corridor management progress.

TOSTADA was initially designed and demonstrated with some common data layers in mind, including congestion, safety, asset condition (bridge and pavement), economic value, and freight value (layers could be adjusted for further demonstration based on local goals, data availability, and other factors relevant to a given corridor analysis). While any one data layer can be considered independently, looking at them together helps to assess the corridor as a whole and identify the segments based on the combinations of relationships in order to better understand what worked, what did not, or what could work in terms of corridor management.

TOSTADA layers these performance data using GIS tools to provide consistent information in one view, relying on data conflated to the highway network segments for a corridor. Each segment has performance calculations for the various data layers included. The outputs are then visualized in color-coded data maps to show the combined performance for each segment of a corridor.

Figure 26. TOSTADA Overview



[198] David Schrank and Tim Lomax, "Improving resource allocation through layered data analysis," March 2017, https://static.tti.tamu.edu/tti.tamu.edu/documents/PRC-14-27-F.pdf.

Balanced Scorecard

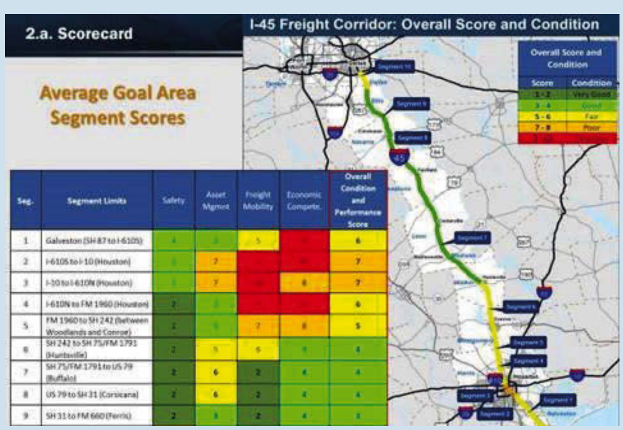
An early iteration of the TOSTADA tool is the Balanced Scorecard. This tool was used as part of the Texas Department of Transportation's (TxDOT) I-45 Freight Corridor Plan. A set of eight performance metrics used to populate five TxDOT Performance Goal Areas. After review and feedback from TxDOT, the TxDOT Performance Goal Areas were narrowed to four (shown in the left-hand column of the table below). Each performance area had one or more performance measures (shown in the middle column of the table below).

TFMP Goal	I-45 Corridor Performance Objectives	I-45 Corridor Performance Measures	Threshold Benchmarks	Criteria Basis
Safety	Improve I-45 Truck Safety	Crash rates on I-45 for Trucks/Commercial Vehicles	Truck crash rate < 120.7/mtvm[1]	Lower than state rate for facility type
			Truck fatality rate < 1.20/mtvm[1]	
Asset Management	Maintain I-45 in State of Good Repair	Pavement condition	<5% of miles at International Roughness Index (IRI) > 170	FHWA Pavement Performance Standards
		Bridge condition	Deck, Superstructure and Substructure Rating of 5 or better	TFMP standards
		Bridge vertical clearances	% or # >=18 '6"	TFMP bridge clearance policy recommendations
			% or # >= 16'	Current FHWA design standard
Mobility and Reliability	Improve truck travel speed	Average Daily Level of Service	Urban/Suburban: LOS D or better; Rural: LOS C or better	TxDOT Roadway Design Manual
		Average daily truck speeds	80% of posted speed	National Performance Research Data Set, 2014
Economic Competitiveness and Efficiency	Improve Truck Travel Reliability	Truck Reliability Planning Time Index	<3.0 ratio of 95th percentile peak to off-peak speeds	National Performance Research Data Set data, 2014

1. Million truck vehicle miles

TxDOT divided the I-45 corridor into ten segments and computed scores from performance measures under each goal area for each segment. Certain metrics were "point" metrics (e.g., a bridge with clearance issues), while others were "continuous" metrics (e.g., pavement condition across an entire segment). Then, all the point scores in a segment were combined into a total score. The higher the total score, the poorer that segment was performing. The combined metric scores (e.g., bridge clearance + bridge condition + pavement condition) for each segment became the Performance Goal Score (e.g., Asset Management Score).

The same procedure was repeated for the other Goal Areas. Color coded maps were produced for each performance measure and each Performance Goal. Finally, all the Goal Area scores were added and weighed to produce a final Score Card for each segment of I-45 (shown in graphic below). TxDOT produced a single map showing visually how the corridor was faring.



Each map color scale shows performance or condition scaled from poor condition (low performance) to good condition (high performance). The color display changes between map layers and shows a variety of factor-specific elements.

The underlying data can then be indexed into one composite score or index. Each data layer results in its own index. For example, congestion may be reflected in terms of delay per mile (DPM) resulting in number of hours, while a ratio-type index such as pavement quality may have a value of one or less depending on the measure. It would be necessary to rescale these performance indicators to build a composite score. This is accomplished by scaling the individual layer indicators to a range between zero and one, and adding a weighting and prioritizing the scaled indices from one data layer or several data layers depending on the corridor management goals and objectives.

TOSTADA is a tool that allows corridor management agencies to understand the full need for, and effects of, transportation investment either in capital projects or operational/Transportation System Management and Operations (TSMO) treatments.[199] Too often, these discussions are focused on engineering evaluations when important economic and quality-of-life concerns may be addressed by the projects, programs, and policies being considered. TOSTADA's integrated maps provide a comprehensive and consistent set of information that can improve project comparison and selection, public engagement, and awareness of the relationship between mobility, safety, freight, economic value, and asset conditions.

As an example, the TOSTADA approach was applied as a demonstration to the I-45 corridor in Texas from Galveston to Dallas. For this example, data were collected for the following four data layers for each highway segment along the corridor:

- *Freight Commodity Value* – a FAF-based value for commodities that are flowing on a corridor, estimated based on roadway type (e.g., interstate, freeway, or arterial).
- *Congestion* – DPM was used as a congestion measure because it is a defensible, industry-tested, and -approved measure of congestion level weighted by volume of traffic and normalized by mileage.
- *Economic Value* – the value of GDP in the county where the highway segment is located in relation to the state's GDP.
- *Pavement* – the score of the pavement quality along the corridor, which helped to provide a sense of asset condition.

The TOSTADA analysis entailed the following steps:

4. A value was assigned for the four layers for each segment of I-45. These values were scaled from smallest (zero) to largest (one) to appropriately compare across the layers.
5. A base index was developed to show what the index is with all four categories weighted the same (25 percent). This base score is intended to compare other scenarios where the weighting has been changed.

[199] David Schrank, "TOSTADA Data Integration Framework (TOol Using STAcked Data) ," 2018, https://static1.squarespace.com/static/59480f9cc534a57e3a1b9f15/t/5b68978870a6add62bf66859/1533581237237/David+Schrank_TOSTADA_Data+Integration+Framework.pdf.

6. Three more scenarios were developed to show the corridor's performance when each category is weighted higher than the others.

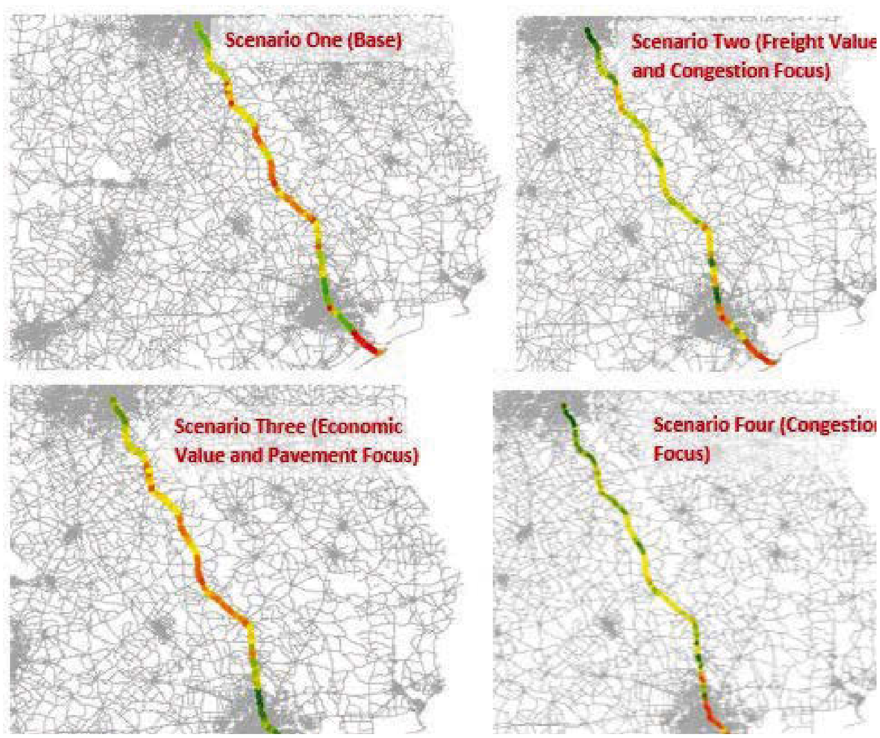
Figure 31 below shows the varying weights attributed to the base and alternative scenarios:

Table 21. Base and Alternate Scenarios Used in TOSTADA Analysis

Scenario	Focus Measure	Measure Weighting			
		Freight Commodity Value	*Congestion (DPM)*	*Economic Value*	*Pavement*
One	*Base*	25%	25%	25%	25%
Two	*Freight Value and Congestion*	40%	40%	10%	10%
Three	*Economic Value and Pavement*	10%	10%	40%	40%
Four	*Congestion*	10%	70%	10%	10%

Maps for each of the four scenarios were generated showing the index based on the weighted measures. For each map (shown in **Error! Reference source not found.**), the results change, as shown by the segment locations colored red (low performance) or green (high performing). Generally, the maps show that performance is lowest near the southern end of the corridor in the Houston region. In scenarios one and three, low performance is identified in the middle to north of the corridor.

Figure 27. Spatial Environment Created for the I-45 Corridor in Texas Using TOSTADA

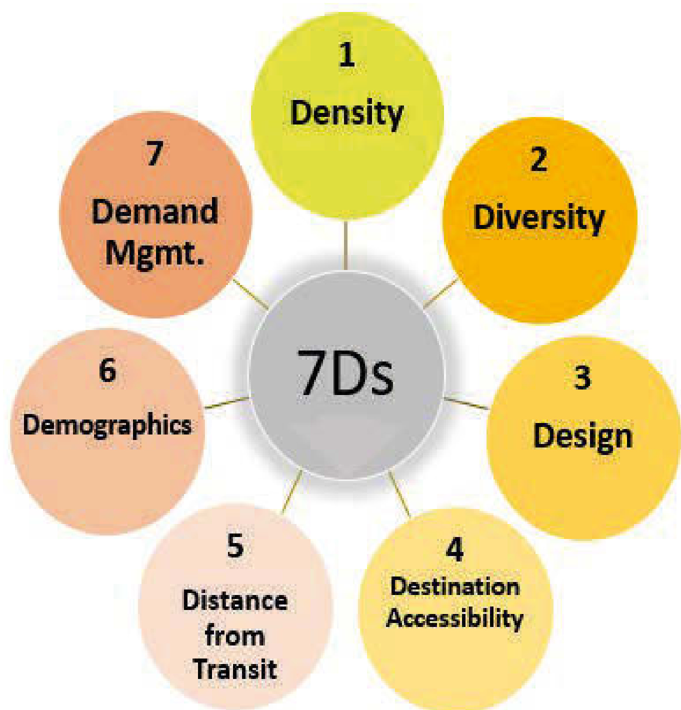


Given the variability in results when different weighting is used, it is important to weight the categories based on the goals of corridor management efforts. If the goal is to improve congestion, DPM should be prioritized. If the effort seeks to manage assets, a different picture will emerge. If it is more holistic, a base index where weights are the same will help to evaluate performance altogether. Even if the goals are specific, it is important to adjust the weights and generate different visualizations for awareness of the interrelatedness of different data layers. This will help in discussions about corridor management efforts and the ways they can drive impacts in different ways, and how particular projects, programs, and policies could be incentivized or disincentivized accordingly.

12.4.1 7-D Integration

The 7-D Integration approach can be adapted for corridor analysis by transportation agencies though it does not provide a spatial approach. An Excel-based model has been developed and is being validated with practitioners. The model provides a calculator that assesses strategies quantitatively and helps in scenario-building for corridor management planning.

Figure 28. The 7-Ds



The 7-D approach entails the analysis of strategies in relation to the "7-Ds" – density, diversity, design, destination accessibility, distance from transit, demographics, and demand management (Figure). Strategies are assessed to the degree to which they integrate the 7-Ds.

As an example, the 7-D approach can be used to examine land-use strategies with the goal of reducing vehicle miles traveled (VMT).[200] Strategies that score higher are those that exhibit the following characteristics:

1. *Density* – Strategies that promote "a lot close by" will encourage walking, biking, and transit ridership and decrease VMT per capita. Thus, they score higher than strategies that do not encourage density and therefore induce driving.
2. Diversity – High-scoring strategies include form-based codes and other strategies to increase mixed-uses and reduce restrictions on specific kinds of uses that bring people closer to the things they need. These are strategies that result in less driving.
3. *Design* – Strategies score higher if they ensure that the local street system has more connections, fewer circuitous paths, and fewer cul-de-sacs. This includes "Complete Street" designs, which promote walking, biking, and transit use, as well as shorter drives.

[200] Michael Brown, "7-D's of VMT Reduction," Metro Analytics Blog, October 27, 2019, https://blog.metroanalytics.com/2017/03/20/7d_vmt/.

4. *Destination Accessibility* – High-scoring strategies are those that provide transit access to popular destinations (e.g., theaters and sports arenas) attract people from all over, and, in turn, reduce VMT.
5. *Distance from Transit* – Strategies that encourage transit-oriented development score higher than others. This includes minimum floor area ratios near transit stations, minimum zoning standards within a quarter-mile of a rail or bus rapid transit station, replacing parking minimums with new mobility contributions (e.g., credits for carsharing).
6. *Demographics* – Strategies are encouraged if they design with changing demographic needs in mind. Thus, strategies score higher when they target younger generations and seniors who are least likely to want to drive by facilitating walkable, mixed-use development.
7. *Demand Management* – High-scoring strategies include those that create alternatives to driving, incentives to use alternatives to driving, disincentives for single-occupant driving, free or reduced-fare transit services, or removal of parking minimums. These strategies reduce demand to match supply, making it easier and desirable to choose alternatives to driving. Strategies that do not score well increase supply to match demand (e.g., highway widening).

In the same way, the 7-D approach can be applied to assess freight supply and demand and understand freight movement and use along a corridor.

1. *Density* – Strategies that facilitate industry clustering will leverage synergies of supply chain clusters. Thus, they score higher than strategies that do not encourage such density. A potential measure of density is concentration of freight activity along a corridor.
2. *Diversity* – High-scoring strategies provide modal options and a variety of freight support services at the intersection of long-haul and last-mile corridors. Such diversity can be measured by the types of industries found along and around a corridor through a review of industry mix.
3. *Design* – Strategies score higher if they include freight design elements that consider pavement, bridge, and geometric factors accommodating large trucks and, depending on the local economy, overweight or oversize vehicles. Freight-oriented design will consider the design profile of the roadway and characteristics needed for freight trucks of various sizes and weights.
4. *Destination Accessibility* – High-scoring strategies are those that provide competitive alternatives for freight traffic to ease access to important domestic and foreign trade markets. This may be measured by the ability and time to arrive at a destination with or without delay, as well as the availability of options for freight movement.
5. *Distance from Transit* – Rather than encouraging transit-oriented development, a freight-oriented 7-D analysis would assess how well a strategy eases the time or cost to reach other modal alternatives or increases options to change modes. “Freight fluidity”, the concept of measuring the performance of all the trips that goods make across all modes from manufacturer to consumer, is a growing area of performance measurement on this topic.
6. *Demographics* – Changes to market strategies are encouraged if they, for example, allow truck drivers to complete their routes in a single day and return home each night. This may be measured by calculating how large the workforce is in a given area and how far they need to travel to a workplace or freight destination.
7. *Demand Management* – High-scoring strategies include those that provide lower-cost alternatives to freight delivery that reduces delivery times. Such alternatives would reduce costs primarily related to labor and fuel to influence demand.

12.4.2 Profiling

Another spatial environment creation tool that can support corridor management projects and planning efforts is profiling analysis. Profiling involves a self-assessment to evaluate whether a corridor is meeting a policy goal for a corridor management effort. Goals can range from the adoption of traffic management technology to walkability to multimodal throughput to environmental sustainability.

As an example, a transportation agency could conduct technology profiling for a signalized arterial corridor to determine where the corridor is in its journey to achieving a high level of technology. The agency could conduct annual self-assessments to determine any progress in the corridor in the adoption of technology, which can help outline a strategy for the next year. As shown in Figure , the assessment would ask a series of questions related to traffic signals, roadside units collecting information and data, communications capabilities, traffic management centers, and the ability to remotely adapt or troubleshoot issues. Depending on the answers to the questions, the corridor would be rated as having a low, moderate, or high level of technology.

Figure 29. Technology Profiling Analysis

Application Example of 3 corridors			
	Low	**Moderate**	**High**
1. Does the corridor have traffic signals or roadside units?	No (Worth 0 points)	No (Worth 0 points)	Yes (Worth 1 point)
2. Does the corridor have roadside units that collect or distribute information?	No (Worth 0 points)	No (Worth 0 points)	Yes (Worth 1 point)
3. Are there any communication capabilities along the corridor, such as fiber or cellular?	No (Worth 0 points)	No (Worth 0 points)	Yes (Worth 1 point)
4. How do the signals or roadside units communicate operating information to a traffic management center (TMC), data center, or transportation department?	No communication, we monitor based on physical visits or calls from drivers (Worth 0 points)	I don't know (Worth 0 points)	Fiber (Worth 1 point)
5. If there is communication with a TMC, is a system in place for the TMC to remotely adjust and troubleshoot issues?	No, the signals do not communicate with a TMC (Worth 1 point)	Yes, a TMC receives data from signals and can adjust remotely (Worth 0 points)	Yes, a TMC receives data from signals and can adjust remotely (Worth 0 points)

Profiling could also be used to determine whether improvements have improved walkability in a corridor. As shown in Figure , the self-assessment would rate the corridor before and after design or other improvements have been completed to determine where it is between the best and worst that could be imagined. The assessment asks for a rating of cross-section and top view design, speeds, transit availability and frequency, parking, demographics, road network, and zoning. This approach was utilized by the Logan City Main Street Partners, as detailed in APP 5.8 Walkability

Figure 30. Walkability Profiling Analysis

	A	B	C	D	E	F	G	H	I	J
1	**Corridor Walkability Calculator**	Logan Main				Before	After	Worst	Ave	Best
2	**Base/Build: Logan Main Street, One-way Couplet**			Scale of 1-100		61	91	1	50	100
3	Desired or Likely Future Area Type (30-yrs out)	Urban								
4	Corridor involves mainly two-way or mainly one-way intersections?	2	1			Point Summary				
5	**Design Attributes: Cross Section (Bike/ped, trees, lanes, medians, etc)**	Before	After	Ok	Ideal	Before	After	Worst	Ave	Best
6	Sidewalk Width, (FT)	10	10	6	8	2	2	-1	1	2
14	Pedestrian Refuge in Median/Cross-Walk?	No	Yes	No	Yes	0	2	0	0	2
15	**Design, Cross-Section Subtotal**					1	20	-11	1	18
17	**Design Attributes: Top View (driveways, crossings, intersect.)**	Before	After	Ok	Ideal	Before	After	Worst	Ave	Best
21	If two-way intersections, select dominant type (6 options)	5				-1.5	0	-3	-1.5	3
22	If one-way intersections, select dominant type (8 options)		2			0	1	0	0	0
23	**Design, Top-View Subtotal**					2.5	6	-11	-1.5	8
25	**Operational Attributes: Speed, Transit**	Before	After	Ok	Ideal	Before	After	Worst	Ave	Best
26	Speed: Either posted or frequently observed (if faster than posted)	40	35	35	30	-5	-2.5	-7.5	-2.5	0
27	Transit peak period frequency (minutes - zero if no transit)	30	30	30	15	2	2	1	2	3
28	Transit: Free Fare? ("Yes" if Free or if Pass <= $50/yr; Otherwise "No")	No	No	No	Yes	0	0	2	2	0
29	Transit: dedicated lane or HOV/HOT lane?	No	No	No	Yes	0	0	0	0	2
30	**Operational Attributes: Speed, Transit: Summary of Points**					-3	-0.5	-4.5	1.5	5
32	**Neighborhood: Parking, Network Type, Demographics**	Before	After	Norm	Ideal	Before	After	Worst	Ave	Best
33	Parking Policy (1=Significant required, 2=Not required, 3=Max allowed)	2	2	1	2	0	0	-2	0	2
34	Network Type (1=Haphazard, 5=Tight Grid)	5	5	2	5	4.5	4.5	-1.5	1.5	4.5
35	Bldg & Zoning (1-4 options, See Note)	3	4	3	4	4	5	-5	0	5
36	Demographics, Leans Elderly?	Yes	Yes			2	2	-2	0	2
37	Demographics, Leans Lower Income or young adult?	Yes	Yes			2	2	-2	0	2
38	**Neighborhood Attributes: Summary of Points**					12.5	13.5	-12.5	1.5	15.5

12.4.3 Step Six: Quantify Corridor Impacts Using a Spatial Corridor Impact Analysis Tool

As described above, the level of work to quantify corridor impact analysis may depend on agency resources and access to data. Assuming an agency falls into the middle and high resource categories for geospatial tools or data analytics, this section provides steps to follow in applying the recommended tools.

Of the tools recommended above, the TOSTADA tool offers the most relevance to transportation agencies in that it uses data conflated to highway segments. Therefore, the framework here demonstrates this approach.[201] Suggestions for weaving in elements of other tools are provided later. TOSTADA has been described in similar detail in the APP 5.3 TOSTADA. The following goes one step further, providing the procedures to apply to quantifying corridor management impacts using the TOSTADA approach.

12.4.4 Data and Overview of Procedure

Under the TOSTADA approach, geospatial analysis typically includes data layers for congestion, safety, pavement condition, bridge condition, economic value, and freight value. These performance data are layered using GIS tools to provide consistent information on topics of interest in one view. TOSTADA, like other geospatial tools, relies on data conflated to the highway network segments for a corridor. Each segment has performance calculations for the various data layers included. For example, each segment could have congestion and pavement results. Then, these results could be turned into an index between zero and one and have a weighting applied to each segment. The outputs could then be visualized in color-coded data maps to show the combined performance for each segment of a corridor.

The TOSTADA spatial approach can also incorporate other data or spatial analysis tools. For example, data from a 7-D approach can be used in a TOSTADA analysis as long as the data can be conflated or coded for each highway segment. Using both 7-D and TOSTADA, a corridor analyst can come up with scores for density that can be translated to the highway segments in a defensible way. In addition, those density scores could be layered with other data to provide a fuller picture of corridor condition or performance.

12.4.5 Considering Data Layers

It is important to use a range of interrelated data layers when looking at a corridor because, together, they help to paint a holistic picture of performance. These relationships are described through the following data layering examples:

Congestion: The addition of a congestion data layer with a safety layer helps to more effectively pinpoint the cause of some safety issues. Congestion sometimes causes safety problems, and in

[201] Note that TOSTADA has been developed for demonstration purposes only. It has not been adopted as a formal means of corridor analysis by a transportation agency. However, its utility as a potential application of data for spatial impact analysis makes it an appropriate method to feature in this section.

some cases, safety problems lead to congestion. An example of how congestion and safety are tied together is when strategies for reducing traffic congestion improve driver safety by decreasing the opportunity for rear-end crashes.

Safety: Safety is a top goal for transportation systems, and safety information can be divided into two major factors: crash frequency and crash severity. Minimizing both is important, and the corridor management process must recognize that there are many interrelated factors that ultimately lead to crashes. Safety is related to congestion, as described above. It is also associated with asset conditions in that hazardous pavement or bridge conditions present safety hazards, which are a major cause of concern and usually drive the prioritization of roadway investments.

Pavement Condition: Pavement condition is tied to safety in that higher quality pavement gives drivers better traction and control of their vehicle. Pavement condition is also an important safety factor during precipitation and other weather conditions. Pavement ride quality can be improved by smoother roads, which improve driver satisfaction and safety.

Freight Value: Tracking the value of commodities in trucks on roadways provides decision-makers with a quantifiable means of understanding the economic impact of one road segment relative to another when determining investments. A road transporting more commodity value may have more economic significance than another, and, thus, for agencies with constrained capital programs, be prioritized for limited funding to help economic conditions.

Economic Value: Understanding economic value is helpful when considering the impacts of investments or management decisions in a corridor. Congestion is related to economic value in that delay adds a cost to people and goods in wasted time and fuel.

These are just a few examples of the relationships among data layers. While any one data layer can be considered independently, looking at them together is helpful to: (1) assess the corridor as a whole; and (2) identify those segments, based on the combinations of relationships, that are performing or in need of a particular combination of corridor management treatments.

12.4.6 Mapping and Indexing Data

The purpose of creating spatial environments for corridor analysis is to help illustrate the ramifications and policy effects of corridor management comprehensively. Therefore, by mapping layers together in one application, all information for a given corridor can be viewed together. This can prove important for decision-makers because it provides a way to identify problem locations and assess solutions. Mapping the data layers together and using the underlying data to create a score or index is useful to see performance throughout the corridor and even rank segments along the roadways.

The TOSTADA model uses GIS tools to demonstrate the individual map layers for the data sources that are selected. For the greatest clarity, analysts using TOSTADA should color code data results differently. For example, they should make each map's color scale reflect performance or condition. Each map should show a scaling from poor condition (low performance) to good condition (high performance) by changing the color. Red (low performance), yellow, and green (high performance) are recommended color scale options. This will help pinpoint the performance for the individual data categories (e.g., congestion).

The underlying data can then be indexed into one composite score or index. Each data layer results in its own index. For example, congestion may be reflected as DPM, resulting in number of hours, while a ratio-type index such as pavement quality may be one or less depending on the measure. Analysts should rescale these performance indicators in order to build a composite score. This can be done by scaling the individual layer indicators to a range between zero and one. Then, the analyst can add a weighting and prioritize the scaled indices from one data layer or several data layers depending on their goals and objectives.

12.4.7 Data Inputs

The following provides examples of the types of performance measures a corridor management agency might want to consider when using a TOSTADA approach. These were created as part of a TOSTADA proof of concept developed for I-695 for the Maryland Department of Transportation (MDOT).[202]

[202] David Schrank and Tim Lomax, "TOol Using STAcked DAta," TOol Using STAcked DAta, October 2014, https://trid.trb.org/view/1408289.

Congestion

The congestion layer uses measures such as the TTI or DPM. Congestion levels on the road segments in the corridor can be compared on a scale of "good" (colored green) to "bad" (colored red). Looking at congestion, as measured by DPM, alone, one can observe the most congested segments within a corridor (Figure). Annual congestion costs can also be computed to provide an indication of the costliest segments along a corridor based on hours of delay (Figure).

Figure 31. Congestion (Annual Delay per Mile) Example

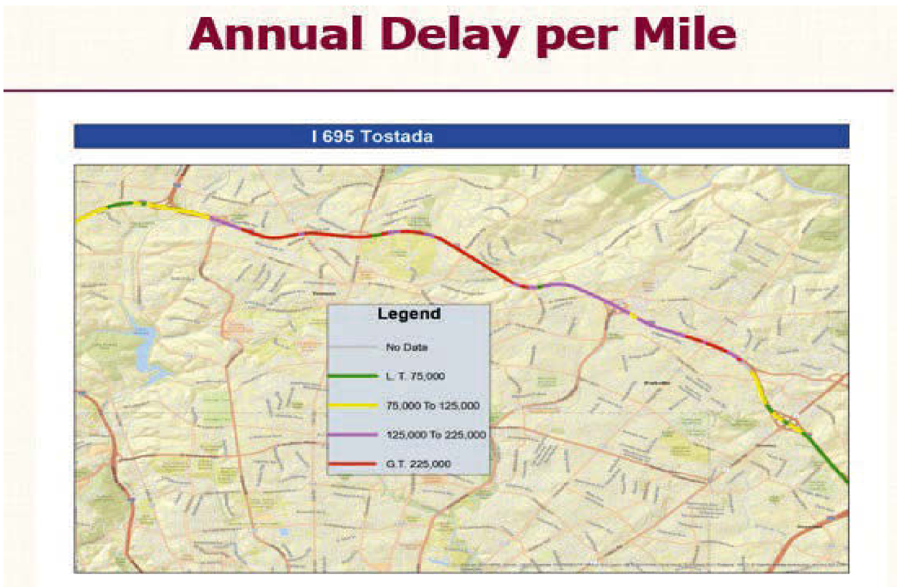
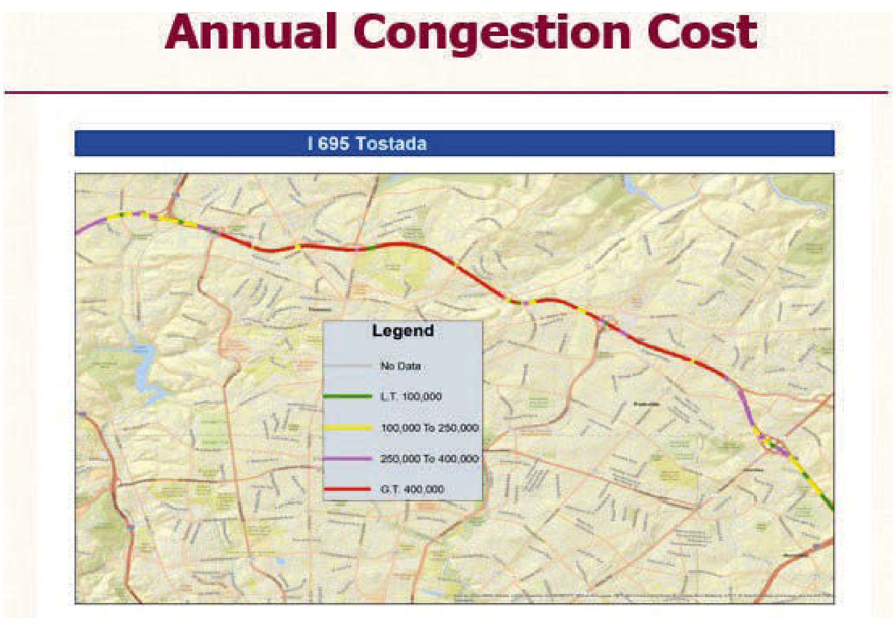


Figure 32. Congestion (Annual Congestion Cost) Example

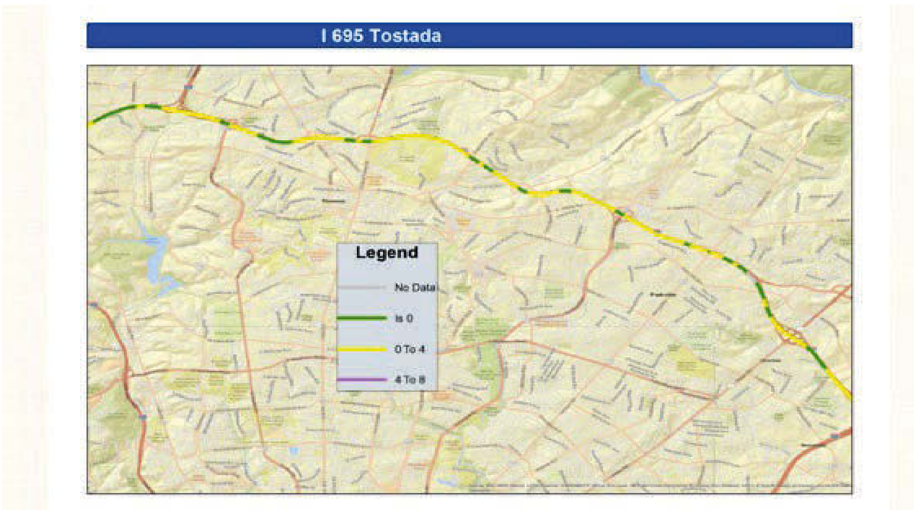


Safety

The safety layer might focus on crashes such as injuries and fatalities for all traffic and commercial vehicle crashes. It could also focus on property-damage-only (PDO) crashes (Figure) or injury crashes (Figure). This allows for the comparison of crashes or other safety indicators by segments of the corridor to identify the worst performing sections.

Figure 33. Safety (Property Damage Only Crashes) Example

Figure 34. Safety (Injury Crashes) Example



Pavement and Bridge Condition

Asset condition measures to consider in geospatial corridor analysis include pavement and bridge condition. A pavement condition layer could use a state's grading scale and International Roughness Index (IRI, see page 8 for further detail) for pavement quality. State DOTs collect this data and submit them to FHWA, so it is generally accessible. Corridor segments can be ranked based on their IRI (as shown in Figure) or another scale that is used to identify sections of the corridor in greater need of repair. Bridge condition could be shown in a data layer that uses bridge deck condition data for the worst condition rating within a road segment, as seen in Figure . The rationale for using the worst condition rating on a segment is that the performance of the entire segment is "only as good as its weakest bridge."

Figure 35. Pavement Condition (IRI) Example

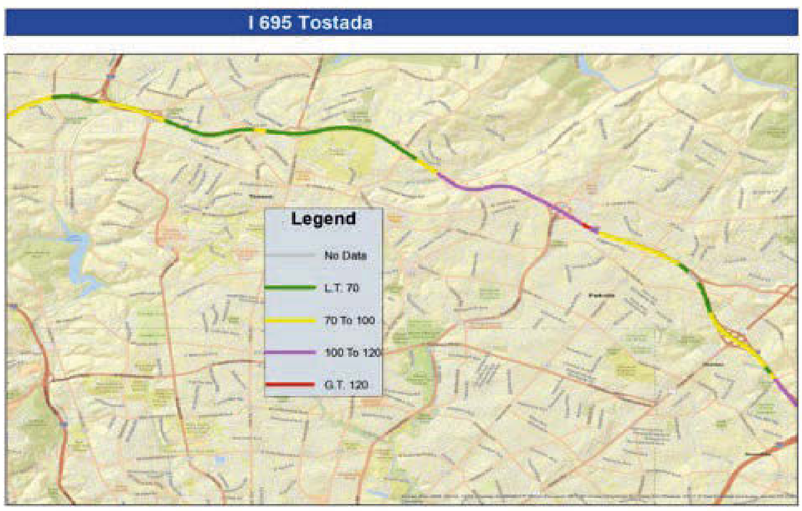
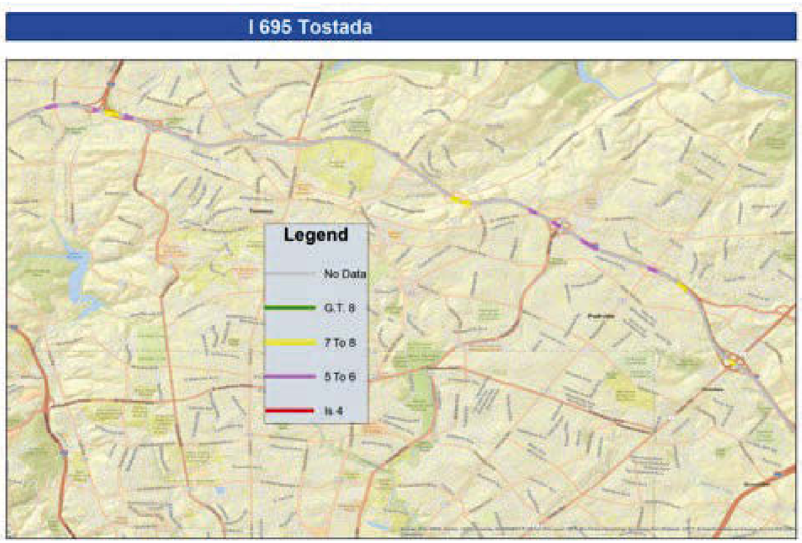


Figure 36. Bridge Condition Example



Freight Value

Corridor management agencies may wish to focus their efforts on goods movement and include a freight value. A freight value layer can illustrate the dollar value of truck commodities carried on road segments estimated using a combination of national and state sources. Figure shows a freight value data layer using daily truck volumes from FHWA's FAF. Figure shows a freight value data layer using annual truck commodity value. This value was calculated from corridor truck volumes combined with FAF information.

Figure 38. Freight Value (Truck Daily Volume) Example

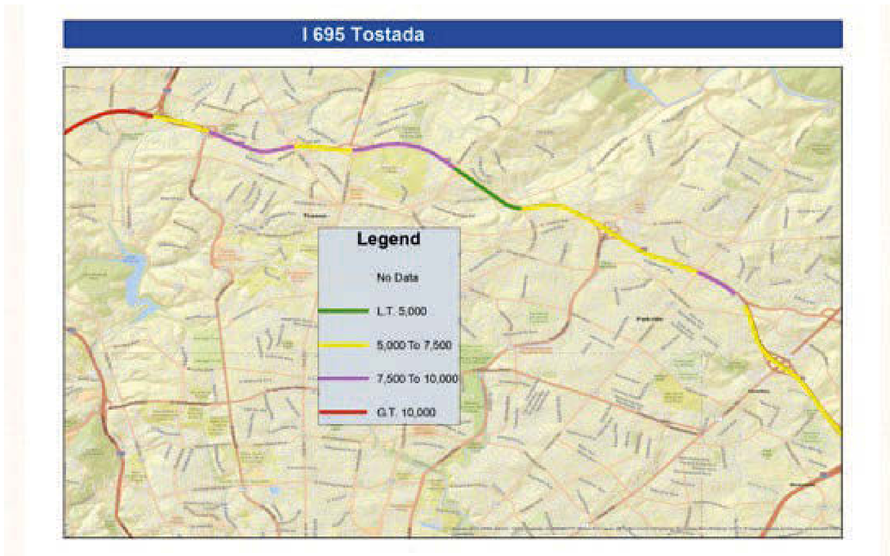


Figure 37. Freight Value (Annual Truck Commodity Value, $mil) Example

Economic Value

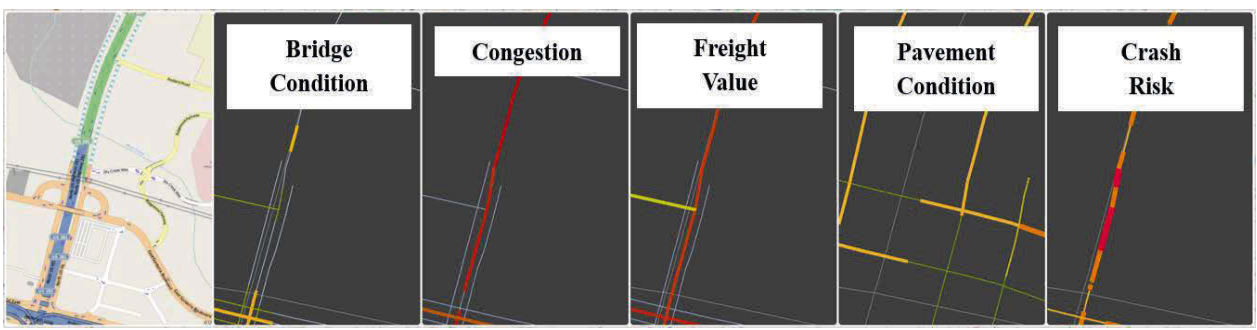
Another important consideration that can form the basis of another data layer is the economic value of a corridor. A corridor management agency may want to develop a measure, showing land values or use changes, to capture this and see how it changes after corridor treatments, especially if the goal is related to economic development or growth.

12.4.8 Process

The TOSTADA tool was named due to the tool's similarity to the way a tostada dish is prepared. A tostada layers many different food ingredients such as vegetables, meat, cheese, and other toppings on a tortilla so that each bite combines all of the various ingredients into one flavor experience. Similarly, TTI created TOSTADA because it helps to understand a variety of project factors in one "visual bite." *A TOSTADA spatial approach layers data and allows the user to develop one indicator based on multiple data sources in order to capture performance.*

Figure 38 shows a TOSTADA analysis of US-281 just north of Loop-1604 in San Antonio, Texas taking each of the individual performance indicators for bridge condition, congestion, freight value, pavement condition, and safety. In this example, congestion, safety, and freight value have high factor scores, as shown in segments that are colored red. This means that this location in the past experienced congestion had a history of crashes, and had a significant amount of freight movement. The pavement and bridge condition have average scores, as shown with the segments colored yellow or green.

Figure 39. Example of different indicator maps layered in TOSTADA



12.4.9 Outputs

A TOSTADA spatial approach can be used to produce maps of individual data layers on one coordinated map for a chosen road link or create one score or an index for each segment to show the combined performance metric for the road segment. The BITE index of scores is a composite that combines indices for data layers in a standardized way. Weights can vary depending on the specific uses of BITE. For example, users may use equal weights for all layers, or freely choose the weight of each index to quantify a comprehensive, prioritized set of condition and performance information for the road network.

Through the maps and BITE, transportation officials may find it easier to:

- Identify transportation problems along a given roadway segment in a corridor;
- Communicate benefits or impacts across multiple assets or performance measures;
- Justify projects that are selected for investment and dollars applied to funding categories;
- Show the effects of treatments on future conditions/performance; and
- Estimate the benefits versus costs of projects in a corridor.

Corridor management agencies can use this type of approach in two phases. The first phase of TOSTADA involves visualizing the data with maps, making comparisons and assessments, and identifying areas of multiple benefits or competing interests. The second phase entails project prioritization and selection by understanding system-wide impacts looking at one index that is based on multiple data inputs and desired weighting. For example, an agency may prioritize congestion reduction, so weighting congestion higher would be reflected in the overall score. The agency can see the segments it needs to prioritize for corridor management at the outset of efforts. The agency can then see how things change after treatments or projects are put in place.

12.4.10 Combinations of Tools

As described earlier in the tools available, options like 7-D Integration or Balanced Scorecard and Profiling allow an agency to look at corridors and impacts not tied to highway networks. This is useful in understanding land-use changes, economic impacts, environmental conditions, and other types of performance that are not usually tied to highway segments. As mentioned above, there are options to score highway segments based on where they are located in different land-uses or zones. This type of information can then be incorporated into a TOSTADA-type approach.

One way these tools can complement each other is by evaluating whole corridors from a 7-D or Profiling-type assessment. Then, through a TOSTADA approach, an agency could identify the segments within those longer corridors that are the worst-performing locations. This approach provides a more revealing picture of the transportation problems and solutions for the regional network. As an example, an area showing a low distance to transit or walkability score through a 7-D or Profiling assessment, respectively, may include roadway segments within the corridor showing, through TOSTADA, high levels of congestion. Together, these tools might suggest that a transit or active transportation strategy could help.

Generally, outputs of other tools, especially if they can be attributed to a roadway segment or attached to highway segmentation, could be used in the TOSTADA approach. More research is needed to explore how to layer and consider the results of various tools and resources that can provide area or corridor-specific information.

12.5 Advice for Creating the Spatial Environment for Quantifying Corridor Impacts

To improve transparency and consistency for corridor investment decision-making, practitioners at transportation agencies will want to take the following actions related to applying spatial analytics for quantifying corridor impacts.

12.5.1 Clearly Define Goals and Objectives

It is important that the agency have a corridor management plan and/or goals and objectives that speak to the aspects of corridor management to be addressed, as well as desired outcomes. All agencies and entities that have regulatory authority in and along the corridor (e.g., planning, operations, land development) should be involved in the development and adoption of the plan and goals. This is critical to determine what matters when assessing corridor management impacts spatially or otherwise.

The corridor management goals and objectives to be addressed through spatial analysis will also need to be shaped by the possible funding sources and stakeholders involved in supporting the implementation of the corridor plans and projects. As mentioned earlier in this document, the geographic area established for the corridor analysis may be impacted by who is funding the corridor management effort and from what sources, as well as the elected officials, constituents, and other influential stakeholders interested in the outcome of corridor management projects. The corridor management goals and objectives should inform the geographic limits of the corridor, keeping in mind the possible funding sources and stakeholders involved in the corridor management effort. Funding and stakeholder support will sustain the corridor management effort through its delivery life cycle, so it is vital to pay attention to both at the outset of corridor management planning.

12.5.2 Perform a Baseline Assessment and Then Measure Routinely

It is also important agencies establish baseline assessments of corridors to understand the current state of the corridor. It is equally important that they undertake routine assessments afterward to assess how well plans have been implemented and are working over a period of time. A baseline assessment can be a first step in understanding results before corridor management plans are implemented. This is especially so in spatial analytics because it is necessary to capture the current state of the corridor and have that geospatial snapshot to visualize how things change over time. Then, repeating the measurement is important so that various jurisdictions can understand how strategies are working (or not) over time.

Additionally, it is important to consider the type of organization and how often to apply the spatial methodology to meet the agency’s needs. This means developing a methodology for when to apply the spatial analysis, the frequency of applying the tool, and how to coordinate with stakeholders to effectively measure impacts. For some organizations, more routine or frequent measurements might be needed depending on the level of activity. For other organizations, such as very large corridor entities, a yearly assessment might be best.

12.5.3 Leverage Available Data

A critical place to start to perform a baseline assessment of a corridor's performance or quantify corridor management impacts is to leverage available data. Practitioners should spend time understanding the data available to the agency. They should assess what data is free, what data may be obtained from sister agencies such as Departments of Planning or Departments of Economic Development, and what federal resources are relevant and accessible. The United States Department of Transportation (USDOT) has numerous resources available for geospatial analysis. Additionally, many Departments of Planning may have the types of data needed and already factored for a specific geographical region, especially for 7-D Integration, Profiling, or Balanced Scorecard approaches. For the TOSTADA approach, the federal government provides NPMRDS data, which can be conflated to HPMS. HPMS data are available at the segment level for asset conditions, volumes, and safety.

12.5.4 Take Advantage of the Focus on Performance Management

With the pervasiveness of performance management at transportation agencies, many resources may already be in place to assess corridor performance. As discussed above, federal resources like the FMT provide performance results easily and can be used by agencies to understand a segment's performance even if it is not tailored directly to the corridor being assessed. Numerous data systems at State DOTs are now available and agencies are growing in geospatial capabilities with resources like ArcGIS Online and Tableau making it easier for agencies to process data and visualize information. This is also critical in communicating performance to the public. As such, it is recommended that transportation agencies take full advantage of such available resources.

12.5.5 Develop Good Data Governance Practice

Data governance and standards should be vetted and used by the agency, corridor management entity, or coalition to ensure consistent, defensible monitoring and analysis that can be compared to other corridors and stand up to rigorous reviews of federal grant applications and other financial pursuits. Establishing strong data governance is key for geospatial analysis because it is important to code data in a satisfactory manner that results in little to no errors when conflating the data to the highway network or on the spatial analysis that is performed.

12.5.6 Communication Among Stakeholders is Critical

Communication among stakeholders is important so that everyone involved understands what is occurring during spatial corridor analysis and why it is relevant to them. Awareness of performance and the ability to see performance holistically, which can be accomplished using spatial analytics, is a necessary component for corridor management success that needs to be considered in applying any framework.

12.5.7 Maintain and Use the Spatial Analysis Environment Once in Place

An agency's momentum in creating a geospatial corridor analysis environment can only be sustained as long as the culture surrounding it remains in place. Thus, the spatial corridor impact analysis tool and procedures for applying it should be maintained and used regularly for corridor management plans and projects. Even if an agency's top policy focus changes from prioritizing highway mobility to transit accessibility, for example, the spatial analysis environment should remain in place as a vehicle for choosing strategies among a range of alternatives and assessing the strategies' effectiveness after implementation. This may require an agency culture of innovation and investments in technology and data analytics, which may change over time.

12.6 Conclusion

This framework provides information that agencies can use to develop spatial analytics. Specifically, it provides the ideas, advice, resources, and steps for developing a spatial environment by taking advantage of existing tools. Spatial corridor analysis is useful to understand where to deploy corridor management efforts and to visually observe how well strategies worked comprehensively across performance categories.

Using this framework, an agency should be able to determine what it can do to undertake spatial corridor impact analysis and at what level. Free, web-based data and analytical tools are available for those with minimal capabilities to buy data or run analytics. Regardless of the resources available to an agency, spatial corridor impact analysis provides an opportunity to fund further corridor analysis and projects generated from it. Spatial analytics done right will show its value to decision-makers and key stakeholders who are aligned in seeking new ways to visualize corridor data comprehensively as a way to understand problems and assess alternative solutions.

Future work stemming from this framework should consider how to better align data or conflate them to join more complicated data sources or those that are not typically aligned to a transportation network. While this framework provides some options, future research could help to advance practices for data conflation and join, for example, some of the concepts in 7-D Integration to ways they can be reflected in a TOSTADA format.