A technical memorandum to

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TEXAS A&M TRANSPORTATION INSTITUTE

TECHNICAL MEMORANDUM

Technical Memorandum on Estimating Planning Level Reliability from Major Projects

Task 4 – Syntheses Development (Synthesis 2 of 3)

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EXECUTIVE SUMMARY

The *Moving Ahead for Progress in the 21st Century Act (MAP-21)* established "performance-based planning and programming" for states and Metropolitan Planning Organizations as part of the growth and development of the nation's transportation infrastructure (1). MAP-21 established seven national goals including system reliability, *"to improve the efficiency of the surface transportation system"* (1). Reliability is the consistency of travel times for the same trip from day-to-day or across different times of the day. The more accurately travelers can plan their trip the more reliable a road network. Ensuring a reliable road network and how it plays into the project implementation process has seen increased interest due to federal performance requirements in MAP-21.

Tools such as those developed by the Strategic Highway Research Program (SHRP 2) assist agencies in measuring the reliability of their road network system and are typically categorized into four groups:

- **Sketch-planning methods**: the least resource-intense tool that assists in early planning stages for agencies to determine the right projects to implement. Methods include:
    - SHRP 2 L03 Analytical Procedures for Determining the Impacts of Reliability Mitigation Strategies.
    - SHRP 2 L07 Reliability by Design
    - SHRP 2 L05 Handbook for Incorporating Reliability Performance Measures into Transportation Planning and Programming.
    - Highway Economic Requirements System State Version (HERS-ST)
    - Project Evaluation Toolkit (PET)
    - Incorporating Active Traffic Management into the Regional Planning Process
- **Post-processing methods**: tools that utilize data from regional travel demand models to provide specific estimations of travel time reliability. Methods include:
    - Intelligent Transportation Systems (ITS) Deployment Analysis System (IDAS)
- **Simulation or multiresolution methods**: tools that use advanced traffic simulation models to test and assesses driver behavior and reaction to nonrecurring events. Methods include:
    - SHRP 2 L08 Incorporating Travel Time Reliability into the Highway Capacity Manual
    - Integrated Corridor Management Modeling in Dallas, Minneapolis, and San Diego
- **Monitoring and management tools and methods**: A key way to provide data for forecasting models by assessing past conditions utilizing real-time and archived traffic data.

Case studies assist the tools described in detail throughout this paper to test the applicability of the tool. Many of the sketch-planning and post-processing methods monetize the benefits of implementing projects that address congestion and reliability to determine the cost-benefit. The sketch planning tools typically require minimal inputs and provide high-level results. Many case studies concluded the tools provided a good indication of the reliability benefits the strategy provided. In addition to tools, frameworks showcase the importance of adding reliability measures into the regional planning process. While not immediate solutions, the frameworks can help instill a holistic approach to the regional planning process to help agencies identify projects that focus on a more reliable network.

Other tools mentioned in this technical memo require more detailed information to conduct an analysis. Testing was not always easy to do with these tools as they had minimal data requirements, which is not always easy to acquire. Even though nine tools were described throughout the paper, a gap existed in the literature about the role the results played into the decision-making process when identifying projects to implement on a corridor or roadway. As the literature advances in calculating reliability it is important to understand the role it plays in overall project implementation.

KEY POINTS

- Reliability is the consistency of travel times for the same trip from day-to-day or across different times of the day. The more accurately travelers can plan their trip, the more reliable a road network. Ensuring a reliable road network and how it plays into the project implementation process has seen increased interest due to federal performance requirements in MAP-21.
- The four categories of tools that calculate reliability include: (1) sketch-planning methods (2) post-processing methods (3) simulation or multiresolution methods (4) monitoring and management tools and methods.
- Each of the respective categories contain tools that test reliability along with case studies that test its applicability.
- Sketch-planning tools are typically the least labor intensive for users and provide a good overview of monetized cost and benefits of project implementation. Simulation or multiresolution methods are the most labor intensive and typically require large amounts of data to test.
- While the tools provide a good understanding of effects of project implementation on reliability, there is a gap in the literature about the overall role these calculations play in the decision-making process when identifying projects for a roadway or corridor.

INTRODUCTION

Congestion impacts on the transportation system are not a new concept for policy-makers, experts, and the public. Since 1991, federal transportation law requires Metropolitan Planning Organizations (MPOs) to address congestion. Lawmakers further extended this law as part of the *Safe Accountable Flexible Efficient Transportation Equity Act: A Legacy for Users* requiring Transportation Management Areas (TMAs) to incorporate congestion management programs in their planning process (*1*). The *Moving Ahead for Progress in the 21st Century Act (MAP-21)* update established "performance-based planning and programming" for states and MPOs as part of the growth and development of the nation's transportation infrastructure (*1*). MAP-21 established seven national goals including system reliability, *"to improve the efficiency of the surface transportation system"* (*1*). Travel time reliability is defined as, "consistent travel times for the same trip as measured day-to-day or across different times of the day" (*1*). Travel-time reliability impacts the entire transportation system and plays a factor for the public when deciding what route to take, what time to leave, and what mode to use. Consistent travel times are a feature of a reliable transportation system and one that allows the public to correctly plan their trip most of the time.

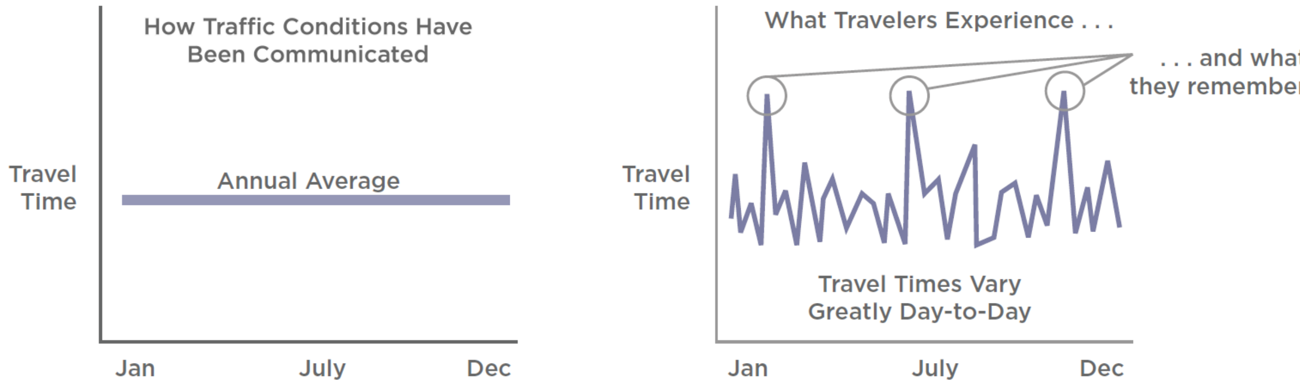
With states and MPOs working to meet federal requirements they also continue to face increased congestion on their road system. According to the 2015 Urban Mobility Scorecard, congestion increased in 95 of America's 101 largest metro areas with commuters spending an extra 6.9 billion hours in traffic and spending an extra 3.1 billion gallons of fuel, contributing to a total congestion cost of $160 billion dollars in 2014 (*2*). Knowing that increasing roadway capacity is not the primary solution to solving congestion the importance of creating and promoting highly-efficient infrastructure is increasingly apparent. Other types of projects that encompass active traffic management, travel options, and pricing strategies can provide operational improvements that enhance the efficiency of a road without increasing capacity.

Performance measures help capture the success and effectiveness of congestion mitigation projects and adding reliability as a component paints a clearer picture of system performance. This technical memo investigates tools, such as sketch planning, that incorporate reliability which can help identify the best projects for a roadway or corridor. While the memo discusses congestion mitigation and mobility strategies it does not advocate for ones. Instead details how the project selection process can utilize reliability as a component.

RELIABILITY: THE MOST IMPORTANT YET LEAST UNDERSTOOD CONCEPT

Recurring congestion occurs every day during peak periods and is expected for the traveling public. For example, a person leaving from work at 5:00 PM may expect to sit in traffic for double the amount of time than if they were to leave during a non-peak period. Its traffic they can plan around and expect as part of their daily commute. Say for example this same person needs to arrive at their destination by 5:45 PM. They know that to account for typical traffic they must allot double the amount of time to get to their destination on-time. On this day, a crash occurs on their route causing their commute time to triple. Because this person did not plan for this non-recurring congestion they arrived late. While recurring delay impacts the transportation system, it's easier to predict and commuters can better plan their trips. Nonrecurring delay is unpredictable by nature, harder to plan, and a more memorable negative experience by travelers, illustrated by Exhibit 1 below.

Exhibit 1. An Illustrative Example of Typical Travel Time Reporting versus What Travelers Experience (*1*).



Dowling et. al. notes that the more inconsistent travel times are the more unreliable they are; making it increasingly difficult to estimate (*1*).

ESTIMATING RELIABILITY

Federal performance requirements in MAP-21 brought increased interest in transportation system reliability. Guerroero et. al. noted reliability as, “the most important variable for trucking yet the least understood” (*3*). “Despite reliability being recognized as one of the most important factors, if not the most important, for freight decision makers, it is rare to consider it in planning efforts around the country” (*3*). In the freight industry, the uncertainty and unreliability of cargo arriving at its destination can cost shippers and consumers thousands of dollars in delay. While not the case for all cargo, “the importance of reliability is in part determined by the time-sensitivity of the shipment, the loss of value during transportation, and the level of importance in the overall supply-chain process” (*3*).

The transit industry places a high value on reliability as untimely service can lead to riders choosing another method of transportation. By incorporating transit signal priority into their signal system agencies can give full, partial, and relative priority to buses at intersections. Furth and Muller (2000) note that, “early applications saw transit priority primarily as a means of improving speed which reduces operating cost and passenger riding time” (*4*). Their paper found “implementing conditional priority—giving full priority at signalized intersections to transit vehicles that are behind schedule—is an effective and practical strategy for improving service reliability on urban bus routes” (*4*).

A variety of common measures classify reliability through (*5*):

- **Statistical Range Methods**: The standard deviation and the coefficient of variation measures which provide an overview of the spread/variation of a corridor or roadway.
- **Planning Time Methods**: Reliability measurement that account for extra travel time that must be factored in for variable traffic conditions. This is captured in measures such as the Planning Time Index or Buffer Index.
- **Tardy Trip Measures, Misery Index (MI)**: The difference between 20 percent of the worst travel times and the mean travel times.

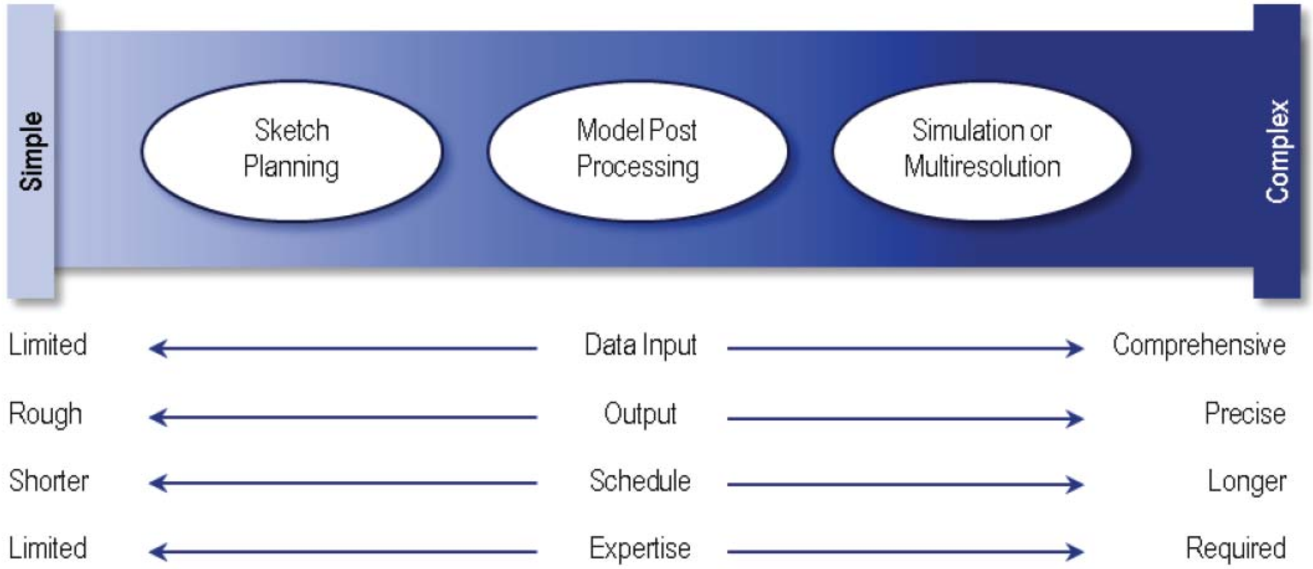
- **Probabilistic Measures**: The probability a trip will fall within a certain amount of time. N. Bhouri et. al. states, "Probabilistic measures are useful to present policy goals, such as the Dutch target for reliability, according to which 'at least 95% of all travel times should not deviate more than 10 minutes from the median travel time'". These measures usually range from the 80^{th} to 95^{th} percentile.

While reliability continues to play a key role in determining the overall performance of the transportation system understanding it at the roadway or segment level is challenging. Tools, methods, and programs can assist agencies with these issues and help identify projects that better address reliability needs and typically categorized into four groups (*8*):

- **Sketch-planning methods**: Consists of a quick assessment of reliability that uses generally available data as inputs to the analysis. This method is the least resource-intense and produces results that can assist in the early planning stages for agencies. While sketch-planning tools are relatively user-friendly, they lack the ability to capture the full variability of reliability as they use static data to produce results.
- **Post-processing methods**: Provides specific estimations of travel time reliability by applying customized analysis routines to data from regional travel demand models.
- **Simulation or multiresolution methods**: Tests and assesses driver behavior and reaction to nonrecurring events through advanced traffic simulation models. This method integrates several standard modeling tools to assess shorter-range and longer-range impacts of various congestion mitigation and mobility strategies.
- **Monitoring and management tools and methods**: Focuses on assessing past conditions by analyzing real-time and archived traffic data, which plays a key role in providing data for forecasting models.

Error! Reference source not found. provides a graphical representation of the strengths and weaknesses of three of the four categories of tools.

Exhibit 2. Strengths and Weaknesses of Reliability Tools (*8)*



The tech memo includes other tools and methods but primarily focuses on sketch planning tools. The next section groups each tool into its respective category and provides an overview along with a case study to showcase its capability.

SKETCH-PLANNING TOOLS

As agencies continuously face budget and resource constraints their ability to select the right project is increasingly important. Sketch planning tools provide a way to test a project's potential viability and understand their impact on a roadway before implementation. The cost-benefit analysis built into sketch planning tools provides transportation agencies guidance during the project/program screening and prioritizing process (*6*).

SHRP 2[1] L03: Analytical Procedures for Determining the Impacts of Reliability Mitigation Strategies

SHRP 2 provides a sketch-planning method for travel time reliability analysis by developing predictive relationships between highway improvements and travel time reliability (*7*). The tool provides guidance on how reliability is impacted by operational strategies and expansion projects. The overall travel time index makes up the method developed for L03 and requires a minimum of six months of data to test (*7*). Exhibit 3 shows the recommended reliability metrics the tool uses.

[1] The Second Strategic Highway Research Program (SHRP 2) is a partnership between the Federal Highway Administration (FHWA) and the American Association of State Highway and Transportation Officials (AASHTO) to foster innovations that allow the transportation community to save lives, money, and time. This program is helping agencies better plan for, design, build, and operate their transportation systems as a whole including better understanding and measuring reliability.

Exhibit 3. Recommended Reliability Performance Metrics for L03 (*7*)

Reliability Performance Metric	Definition	Units
Buffer Index	Difference between 95th percentile TTI and average travel time, normalized by average travel time. Difference between 95th percentile TTI and median travel time (MTT), normalized by MTT.	%
Failure and on-time measures	Percentage of trips with travel times <1.1 MTT and <1.25 MTT. Percentage of trips with space mean speed less than 50, 45, and 30 mph.	%
Planning Time Index	95th percentile TTI.	None
80th Percentile TTI	Self-explanatory.	None
Skew statistic	(90th percentile TTI – median)/(median – 10th percentile TTI).	None
Misery Index (modified)	Average of highest 5% of travel times divided by free-flow travel time.	None

Controlled before-and-after studies provided the best mechanism to test the effectiveness of the tool in predicting the change in reliability from improvements (the overall goal of the tool). Exhibit 4 provides the results of the case studies developed by the tool which found that demand (volume) is a major determinant of reliability. As volume increases and a roadway begins to reach capacity, the roadway is more susceptible to incidents. The tool also found (*7*):

1. Capacity improvements improved recurring congestion nearly every day.
2. Strategies implemented to address disruptions only affect congestion when those events occur.
3. Demand management strategies lead to reliability improvements.
4. Accounting for volumes in relation to available capacity can provide a tool for efficiently allocating operations strategies, particularly incident management.

Overall, the tool helped researchers conclude that reliability is a feature of congestion and that operational treatments and other congestion-relief measures can address unreliable travel times (*7*).

Exhibit 4. Before-and-After Studies for Reliability (*7*)

Case No.	Urban Area	Highway Covered	Improvement	Reliability Impacts (Peak Period)
1	Los Angeles	I-210	Ramp metering: design, field implementation, and evaluation of new advanced on-ramp control algorithms on westbound I-210.	Slight increases in average travel time and Planning Time Index (PTI) were observed. However, subsequent to this evaluation, the algorithms have been adjusted.
2	San Francisco Bay Area	I-580	Ramp metering.	22% reduction in average travel time. 20% reduction in PTI.
3	Seattle	SR 520	Ramp metering.	11% reduction in average travel time. 12% reduction in PTI.
4	Atlanta	I-285, Northern Arc	Ramp metering.	9% reduction in average travel time. 7% reduction in PTI. 3% increase in sustainable service rate.
5	Atlanta	All freeways inside beltway perimeter	Incident management: incentive program for reducing large-truck crash incident duration (90 minutes).	13% reduction in large-truck crash incident duration. 9% reduction in lane hours lost per large-truck crash.
6	Los Angeles	I-710	Incident management: evaluation of pilot project to deploy towing service for big-rig tractor trailers.	10% reduction in average travel time. 20% reduction in PTI.
7	San Diego	I-8	Incident management: expansion of the existing Freeway Service Patrol Beat-7 on I-8.	3% reduction in average travel time. 4% reduction in PTI.
8	San Diego	SR 52	Incident management: expansion of the existing Freeway Service Patrol.	20% reduction in average travel time. 10% reduction in PTI.
9	Minneapolis–St. Paul	I-94	Capacity expansion: add third lane in each direction.	43% reduction in average travel time. 46% reduction in PTI.
10	Minneapolis–St. Paul	I-494	Capacity expansion: add third lane in each direction.	31% reduction in average travel time. 16% reduction in PTI.
11	Minneapolis–St. Paul	I-394	Capacity expansion: add auxiliary lanes westbound.	35% reduction in average travel time. 38% reduction in PTI.
12	Minneapolis–St. Paul	Highway 169	Capacity expansion: convert signalized intersections to diamond interchanges.	16% increase in average travel time. 11% reduction in PTI.
13	Minneapolis–St. Paul	Highway 100	Capacity expansion: add third lane northbound; add auxiliary lane southbound; convert Highway 7 interchange from a clover leaf to a folded diamond.	20% reduction in average travel time. 30% increase in PTI.
14	Seattle	I-405 southbound	Capacity expansion: addition of one general-purpose lane.	11% reduction in average travel time. 11% reduction in PTI.
15	Seattle	I-405 northbound	Capacity expansion: addition of one general-purpose lane.	42% reduction in average travel time. 35% reduction in PTI.
16	Seattle	I-405/SR 167 interchange	Capacity expansion: grade separation ramp connecting southbound I-405 off-ramp with southbound SR 167 on-ramp.	20% reduction in average travel time. 23% reduction in PTI.
17	Minneapolis–St. Paul	I-394	HOT lane conversion.	8% reduction in average travel time. 30% reduction in PTI.

Note: Long study segment = 16 miles; study section influenced by downstream bottleneck.

SHRP 2 C11: Tools for Assessing Wider Economic Benefits of Transportation

C11 provides network-wide estimates of reliability when comparing various project designs by offering "planning level solutions for assessing travel time reliability" (*8*). It categorizes benefits by travel time reliability, intermodal connectivity, and market accessibility. Because this reliability tool assists in planning-level analysis it must be performed at the segment-level and inputs should pertain to homogenous sections of the highway (*8*). The inputs for this tool include basic segment geometry (i.e.

facility type, number of lanes, and segment length); traffic data comprised of annual average daily traffic (AADT), annual growth rate, and truck percentage; and economic information containing the unit values of travel time and reliability (*8*). This tool forecasts the impacts and costs of reliability for individual projects and is applicable to any roadway type (*9*). The outputs are for the entire project length and displayed for the base condition and all improvement scenarios (*8*). Different reliability metrics are produced that allow the user of the tool to "make independent estimates of the value of reliability;" below is a list of those outputs (8):

- Year of Analysis (the future year).
- Recurring delay (hours).
- Incident delay (hours).
- Total delay (hours).
- Overall travel time index.
- 95^{th} percentile travel time index.
- 80^{th} percentile travel time index.
- Percent of trips under 45 miles per hour (mph).
- Percent of trips under 30 mph.
- Cost of recurring delay.
- Cost of unreliability.
- Total congestion cost.

The next section provides two case studies and an overall summary testing the C11 tool.

Kellogg Boulevard Bridge Reconstruction, Minnesota Department of Transportation (MnDOT)

Kellogg Boulevard serves as an integral connection between downtown St. Paul and surrounding neighborhoods. The C 11 tool aimed to measure the impact on reliability, through monetary benefits, of reopening an eastbound lane on a newly constructed bridge by calculating no-build and build scenarios. Passenger vehicles are separated from freight and busses as "travel time reliability holds a different value for freight or busses than it does for commuter traffic" (*10*). The tool approximated that the project would decrease nonrecurring factors for the build scenario by roughly 3,000 hours, saving users $55,000 a year from less variance in unexpected travel times. The tool also indicated that the build scenario proved more effective at improving travel time reliability than reducing delay (*10*).

IH 494/TH 62 Congestion Relief Study, Minnesota Department of Transportation

Two parallel corridors, IH 494 and TH 62, in southwestern Minneapolis experience significant congestion (*10*). The two alternatives evaluated eastbound/westbound HOV and toll lanes along IH 494 to understand "how alleviating congested travel times and inducing more demand along each of these routes impacts network-wide travel time performance" (*10*). The tool evaluated a no-build and a build scenario. The build scenario provided the greatest amount of savings in terms of recurring delay and travel time reliability, and across all three scenarios, reliability nearly had a direct correlation with recurring delay (*10*). Further testing helps ensure consistency among non-recurring-to-recurring congestion ratios.

Conclusion of Case Studies

MnDOT chose the two case studies based on suitability as they were small scale projects. The heavily-researched methodologies produced high level outputs while requiring a minimal level of input. MnDOT valued the ability to measure travel time delay and reliability measures for autos and trucks separately but found difficulty in analyzing a network of segments during the same evaluation.

SHRP 2 L07: Reliability by Design

This spreadsheet-based tool allows agencies to evaluate the cost-effectiveness of design treatments on non-recurrent conditions. While these treatments target reliability improvement they also monetize vehicle delay and crash reductions by providing a broad overview of project monetary benefits (*10*). The guidebook contains a list of design treatments to reduce non-recurrent congestion and lists reasons for excluding other designs. In addition to design-based treatments, the guidebook considers technology-related and support-design treatments as not all treatments provide the same performance for different areas. The following two case studies from MnDOT provide an understanding of the tools' process and its effectives.

Freeway Incident Response Safety Team (FIRST) Program

The FIRST program, implemented by MnDOT in 2003, deploys a metro-wide fleet to monitor the 220 miles of freeway. The program aims to "target incident locations and mitigate the resulting congestion by reducing incident duration and secondary crashes" (*10*). The program was first evaluated in 2004 (FIRST Program Evaluation) and the results were compared to values the tool generated. This helped gain a sense of reasonableness in areas where the tool may not be as effective. The FIRST Program Evaluation calculates benefits from delay, crash, fuel, and emissions savings. This differs from the tool's calculated benefits which includes delay savings, enhanced reliability, and crash savings. Exhibit 5 compares the results.

Exhibit 5. Program versus Tool Evaluation Results (*10*)

	Program Evaluation (2017 $)	L07 Tool (2017 $)
Delay Savings	$26,953	$33,176
Crash Savings	$79,944	$24,778
Reliability Savings	-	$569
Total Benefit	$106,896	$58,523
Program Cost	$7,695	$7,695
B/C	13.9	7.6

The program evaluation and the L07 tool provided similar results, except for a large discrepancy in the crash savings estimations. The differing method of calculating costs most likely attributed to the gap in total benefits among the two.

IH 94 Emergency Pull Offs

The I-35W bridge collapse resulted in the implementation of several emergency pull-offs on the I-94 corridor near downtown Minneapolis. This included adding a lane over the existing shoulder to manage an increase in traffic from a diversion route (*10*). This strategy aimed to reduce incident duration and congestion from incidents by relocating disabled vehicles (*10*). The results of the evaluation indicated a lack in significant reliability benefits most likely attributed to an unsubstantial number of travel times affected by this treatment over the span of a year (*10*). Not only do incidents need to occur for the treatment to take effect, but they must occur during peak periods for significant nonrecurring congestion to accumulate.

Conclusion of Case Studies for L07

With the ease of effort and time to perform a baseline analysis, MnDOT found value in implementing the tool. The tool's ease made it applicable to various scenarios such as, small geometric treatment of a corridor scheduled to undergo construction or rehabilitation; worthiness of appending spot improvements to a corridor while it is undergoing existing construction; and a quick sketch-level assessment of economic effectiveness (*10*). Before this occurs, MnDOT recommends further validation by focusing future research on travel time reliability as both case studies produced low reliability benefits.

SHRP2 L05: Handbook for Incorporating Reliability Performance Measures into Transportation Planning and Programming

This tool aims to provide an overview of procedural and technical approaches that State DOTS and MPOs can use to integrate mobility and reliability performance measures and strategies into their transportation planning and programming processes (7). The handbook provides guidance on creating traffic throughput efficiencies using the existing transportation system before selecting capacity projects or identifying where they cannot reasonably be undertaken. The next section showcases FDOT's efforts in incorporating L05 into their transportation planning and programming process.

Testing the Tool – Incorporating Reliability Performance Measures into the Transportation Planning and Programming (L05)

FDOT conducted a pilot study by matching the L05 products with "FDOT's policies and programs to identify areas of improvement in implementation" (*11*). A subject matter expert for FDOT Anita Vandervalk noted, "What we found through testing L05 is that for reliability to be successfully implemented, it needs to occur in all planning and production phases and when the districts evaluate and recommend or select projects" (*11*). In response to their pilot testing, FDOT published the Planning for Travel Time Reliability Guide and noted gaps in two key processes (1) applying Travel Time Reliability tools to analyze and product reliability, and (2) funding for the types of operational projects that yield the most travel time reliability benefit (*11*). Observations on how they can better incorporate reliability into project section includes (*11*):

- *"Increased cooperation between offices to develop overarching documents, such as the Florida Transportation Plan as well as more specific ones like the ITS Strategic Plan and the SIS Policy Plan, so they specifically address planning for improvements that increase reliability of travel. This cooperation between planning and operations at both the District and Central Offices levels is particularly important."*
- *"To better plan for reliability, it is crucial that operational alternatives (stand-alone as well as in conjunction with capacity expansion) are considered and evaluated during the planning stage."*
- *"Collaborative nature: during the development of the Transportation Improvement Projects (TIPs), MPOs can collaborate internally and with FDOT operations District and Central offices to better plan for reliability improvements. In turn, the District/Turnpike and tentative work programs can make sure to incorporate them. Depending on the budgetary needs, stakeholders may collaborate in a joint effort to submit a legislative budget request."*

In addition to how FDOT can incorporate reliability the guidebook provided methods on how they can adapt it into their current traffic analysis toolset (Exhibit 6) to produce reliability estimates on the effects from operational project implementation (*11*).

Exhibit 6. FDOT Traffic Analysis Tools Used for Project Development (*11)*

Project Development Stage	Level of Analysis	Analysis Tool
Sketch Planning	Generalized Planning	Generalized Service Volume Tables LOSPLAN Highway Capacity Manual
Travel demand modeling	Conceptual Planning	Cube Voyager
Deterministic Operations Analysis	Conceptual Planning Preliminary Engineering Design Operations Planning	LOSPLAN Highway Capacity Manual Synchro, Sidra
Stochastic Operations Analysis	Preliminary Engineering Design	CORSIM VISSIM SimTraffic

Value of travel time reliability (VOR) is a new concept to the traditional valuing travel time (VOT) used in modeling and analysis. VOR connects the monetary values travelers place on reducing the variability of their travel time (*11*).

Highway Economic Requirements System State Version (HERS-ST)

The Highway Economic Requirements System (HERS), first developed by FHWA calculated the benefit-cost ratio of highway investment to assist agencies in the decision-making process. HERSs' primary role was to assist in system and corridor planning but is applicable to project analysis as a screening tool to analyze impacts of project implementation. This software does not directly calculate reliability performance measures, but utilizes the same inputs required for the SHRP 2 C 11 mean Travel Time Index (TTI) equation. The calculated mean TTI can help predict all other performance measures.

HERS (HERS-ST) was developed to assist state agencies in analyzing highway deficiencies for programming and planning purposes (*12*). This version produces outputs that consist of recurring delay rate and incident delay rate to estimate any of the reliability performance measures supported by SHRP 2 C 11 (*9*).

The next section tests this tool through a case study.

Testing the Tool

The Oregon Department of Transportation (ODOT) tested HERS-ST on a 10-mile rural corridor of US-97. This corridor runs through central Oregon and the tool evaluated the 2041 future year build and no build conditions and performances for the corridor (*12*):

- Average Travel Speed and Travel Time
- Average Reliability
- Average Congestion and Delay
- Average User Costs
- Average Crash Rates.

The model used various capacity and demand adjustment scenarios for the corridor to account for different types of incidents. Travel time reliability is especially important for this corridor as it serves as an important freight flow. The model evaluated 80th percentile travel times and the 95th percentile planning time index for the build and no build scenario Exhibit 7 (*12*).

Exhibit 7. Results from HERS-ST Analysis

Scenario	80th Percentile Travel Time	PTI for 95th Percentile Travel Time
Build	1.10	1.36
No Build	1.22	1.25

Project Evaluation Toolkit (PET)

The Project Evaluation Toolkit (PET) uses side-by-side metrics for a host of project types, including capacity expansion, new-link construction, flat-rate and variably-tolled corridors, managed lanes, and various other traffic management strategies (such as advanced traveler information systems, speed harmonization, shoulder-lane use, ramp metering, incident management, and managed lanes) (*13*). PET consists of a five-step model considering four major impact areas: *traveler choices* (and traffic conditions), *traveler benefits* (including travel time savings and travel time reliability improvements), *emissions* (across 14 species), and *crash counts* (by severity). The tool outputs monetary benefits of three projects relative to a base-case (e.g. no-build) alternative, over the project or policy horizon (e.g., 20 to 30 years or more), and discounted to present dollar values (for equitable comparison of benefit-cost (B/C) ratios, internal rates of return, and other performance metrics) (*13*).

- *Traveler Choices and Traffic Conditions:* traffic impacts from project implementation are modeled on a user-created abstracted network with a built-in travel demand model (TDM) module. The tool mimics large full-size regional networks through various conditions times of the day.
- *Traveler Benefits:* the economic impact to travelers is estimated based on changes in travel times, costs, and congestion levels from project implementation. The tool calculates a traveler welfare or consumer surplus based on the user's willingness to pay versus their actual costs to travel. The tool uses origin-destination (O-D) data to understand the concept of travel-time reliability based on the relationship between freeway volume-capacity ratios and travel time variances using traffic data from Cambridge Systematics.
- *Emissions:* estimates the environmental impacts from transportation development projects. The emission rates are based on the facility classification of the road, vehicle speed, climate and seasonal context, analysis year, and vehicle classification.
- *Crashes:* estimates the crash severity for each O-D pair using safety performance functions and key factors including link functional classification, average annual daily traffic, and number of lanes.

The next section describes the congestion mitigation project and how it is evaluated by PET (*13*):

- *Capacity additions:* additional lanes that alter free flow speed and network travel patterns. The tool produces outputs for traveler welfare based on changes in O-D pairs and generalizes costs for the base-case and the alternative scenario.

- *Tolling:* PET computes the impacts of variable tolling at the individual link level for various times of day for the base-case and alternative scenario. The PET assumes tolls increase generalized costs for travelers and are inputted into the tool as a benefit-cost agency benefit. PET provides cost estimates for project financing for each alternative through net present values, rate of return, and payback period based on tolling revenue projects.
- *Managed lanes:* designated lanes that undergo operational strategies (can include pricing, vehicle eligibility, and access control) which are actively managed in response to changing road conditions. PET can accommodate most of the various conditions and provide user benefits based on the alternative scenario.
- *Shoulder-lane use:* allows road users to utilize the shoulder-lane as a travel lane during different times of day. The tool calculates benefits based on the increase of capacity for the impacted links only.
- *Ramp metering:* an active traffic management tool that meters incoming traffic onto the main lanes to ensure optimal conditions for road users. While the tool calculates the benefits of this project a microscopic simulation study using different traffic and geometric conditions may be needed to supplement the tool.
- *Incident management:* strives to specifically deal with non-recurring events such as crashes, disabled vehicles, and spilled cargo. PET estimates the benefits of this tool through travel time savings and emissions due to the reduction of travel speeds.
- *Advanced traveler information systems:* provides travelers with information about road conditions to help reduce the potential of non-recurring and recurring incidents by providing drivers with alternative routes. PET estimates the benefits of these systems in the form of monetized travel time savings.
- *Speed harmonization:* reduction of speed near heavily congested areas reducing stop-and-go traffic that can lead to frustration and crashes (*14*). This strategy aims to improve congestion and traffic performance while the PET estimates benefits from crash reductions.

PET computes an output summary sheet for major project impacts (from the list described above) and financial summary measures for each alternative compared to the base-case scenario. Traveler impacts include welfare, reliability, tolling revenues, and crash costs which are all computed against the base-case scenario. A graph illustrates these results. The reliability evaluation is conducted through anticipated uncertainty in travel times, by understanding the relationship between freeway volume-capacity ratios and travel time variances from traffic data provided by Cambridge Systematics (*13*). Unreliability is multiplied by each user's Value of Reliability (VOR) to determine an overall system reliability cost.

The next section contains a case study testing the tool.

Testing the Tool

Two scenarios on Austin and Houston road networks tested PET. The case studies showcased the usability of PET. Note that these case studies focused on the benefits in emissions and crash reduction when these strategies affect much more including reliability.

- *US 290 in Austin, Texas:* Included three alternatives, varying in pricing structure (no tolling, flat rate toll, variable tolling) surrounding a highway grade separation project in Austin. The tool provided project summary measures for each alternative with initial year benefits, design year

benefits, benefit-cost ratios, and net-present values. It also provided investment estimates required for the construction, maintenance, and operation of each of the scenarios.
- *Interstate Highway 10 in Houston, Texas:* Investigated the operational improvement from speed harmonization.

Incorporating Active Traffic Management into the Regional Planning Process

Active traffic management (ATM) practices such as variable speed limits, queue warning systems, hard shoulder running, and dynamic ramp metering can improve safety and operational components of a road network. Miller and Fontaine developed a sketch-level approach on how agencies can incorporate ATM into their regional planning process. The paper lays a framework to measure the effects of ATM using data that is typically available at a planning level of analysis. Exhibit 8 illustrates this framework through a ten-step process.

Exhibit 8. Framework to Include Active Traffic Management into the Regional Planning Process (*15*)

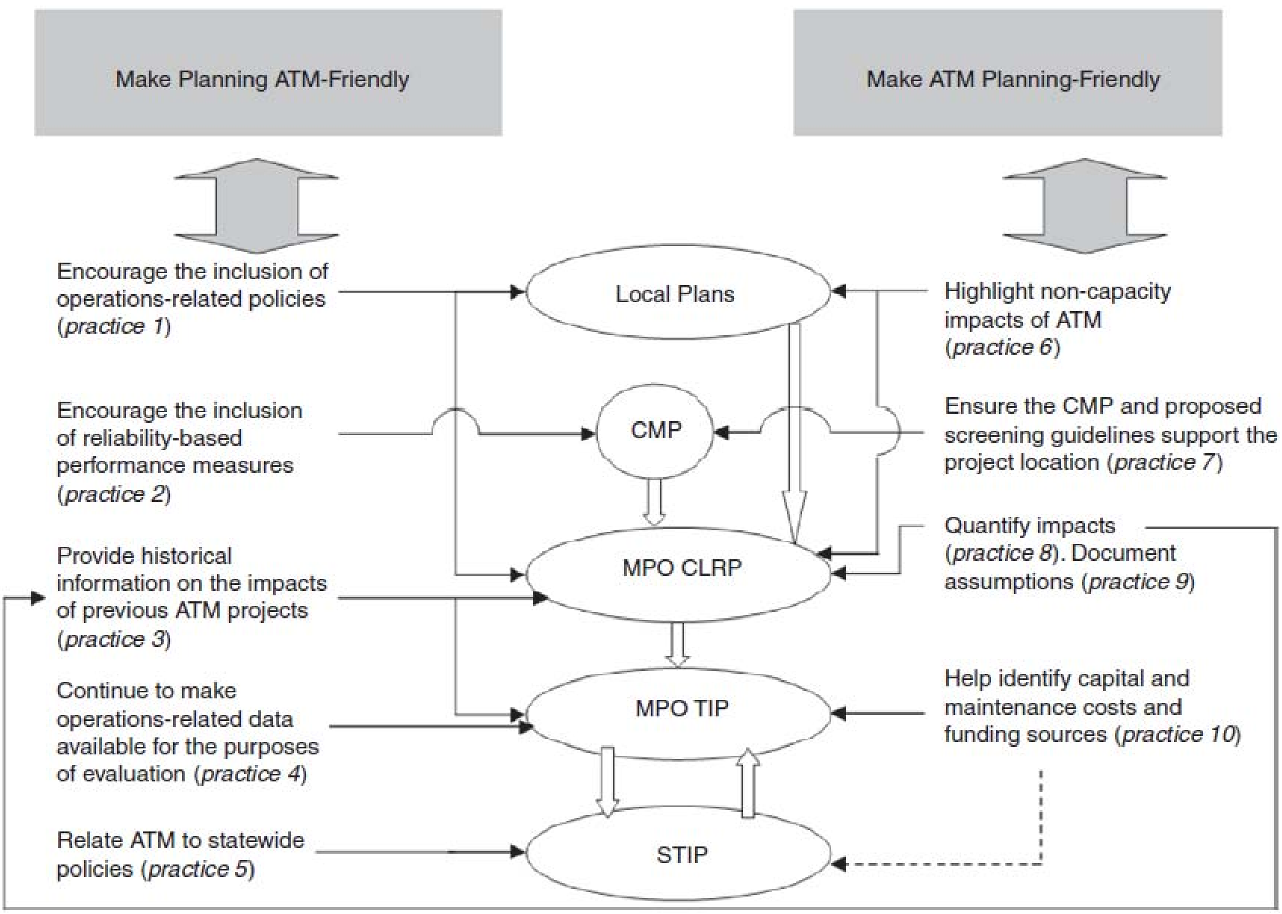


FIGURE 1 Framework for including ATM in planning process, which has been simplified to emphasize linkages with potential ATM initiatives. The outer loop from Practice 8 to Practice 3 shows feedback that should influence future investments (STIP = statewide transportation improvement program).

Practice 5 notes the importance of including reliability-based performance measures when planning for projects since traditional performance measures do not necessarily reflect reliability (*15*). Metrics such as hours of delay and the buffer index help showcase the effect a project has on reliability at the regional level (*15*).

The next section tests the framework through a case study in Washington D.C.

Testing the Framework

A case study helped assist the applicability of the framework to a hypothetical variable speed limit (VSL) system on Interstate 66 westbound in the Washington, D.C. metropolitan area. VSL systems also known as speed harmonization, reduce speed limits based on the current conditions of the corridor helping warn drivers. The objective and policy in the Fairfax County, Virginia plan aimed to maximize the operational efficiency of transportation facilities. The plan identified traditional measures of congestion and reliability-based metrics such as the buffer index to capture the effect of modest improvements in congestion times (practice 2 in the framework) (*15*). The tool estimated one-mile per hour improvements in the 95th percentile travel time from implementing VSLs. This improvement relayed a 7 percent improvement in the buffer index. Practice 8 of the framework strives to quantify the effects of the tool by analyzing the safety, delay, and benefit-cost ratio of VSLs.

The framework aimed to provide a case for the benefit of sketch planning techniques in the regional planning process, before implementing projects. This helps prevent overestimation of certain techniques and determine whether ATM merits further consideration at any additional sites in the region. This framework provided a foundation for what agencies need to look for when conducting their regional planning and identified measures to use in sketch planning tools. VDOT recommends that the results from their case study be used to "guide future decisions about ATM or HSR" (*15*).

POST-PROCESSING METHODS

Intelligent Transportation Systems (ITS) Deployment Analysis System (IDAS)

Developed by the Federal Highway Administration (FHWA) to help local, regional, and state planners understand the benefits and costs of investing in ITS deployment. ITS emerged as a leader in solving many transportation issues since the costs associated with implementation were more reasonable than building new roads. ITS uses the current system to create efficiencies.

IDAS uses a four-step model to forecast travel demand on the transportation system and then compares a set of transportation improvement strategies to base conditions to determine a benefit-cost ratio (*16*). Previous models before IDAS evaluated the effects of project implementation but lacked the ability to understand the potential effects of operational improvements such as ITS. IDAS utilizes traditional four-step modeling tools but executes its own travel demand model to determine new travel patterns which emerge from ITS improvements; the overall framework for IDAS includes (*16*):

- *Input/ Output Interface*: data from the four-step planning model is inputted into the IDAS software and a base-case scenario is established to understand the regional transportation network in terms of nodes, links, and the number of trips from each origin to destination for the desired year.
- *Alternatives Generator:* allows the user to select the desired ITS components for the transportation network from 12 major categories.

- Arterial Traffic Management Systems.
    - Freeway Traffic Management Systems.
    - Advanced Public Transit Systems.
    - Incident Management Systems.
    - Electronic Payment Collection Systems.
    - Railroad Grade Crossings.
    - Emergency Management Systems.
    - Regional Multimodal Traveler Information Systems.
    - Commercial Vehicle Operations.
    - Advanced Vehicle Control and Safety Systems.
    - Supporting Deployments.
    - Generic Deployments.
- *Benefits Module*: This module quantifies the results of the desired ITS components in the previous step and incorporates an internal travel demand model to re-evaluate the travel patterns from the base-case scenario. The tool reports benefits associated with ITS improvements through the following submodules:
    - Travel/Time Throughput Submodule.
    - Environment Submodule.
    - Safety Submodule.
    - Travel Time Reliability Submodule.
- *Cost Module*: This module tracks estimated costs to deploy selected ITS components including equipment costs, the percentage of public versus private funding, deployment schedule, and use of shared equipment.
- *Alternative Comparison Module*: The final module compares the benefits and costs of ITS components to the base-case scenario through a monetary value.

The next section tests the tool through a case study.

Testing the Tool

Sadek and Bahh documented the test of their tool through a case study paper on the cost-effectiveness of "ITS Deployment in a Medium-Sized Area". They analyzed benefits of deploying ITS in two different areas in Chittenden County, Vermont. This technical memo only analyzes the method of calculating travel-time reliability and the sensitivity of ITS deployment on the model's parameters, although the tool measures beyond these metrics (*17*).

Shelburne Road Smart Corridor Project deployed limited closed-circuit TV (CCTV) cameras or nonintrusive detection devices, such as the remote traffic microwave sensor (RTMS), portable variable message signs (PVMS), pre-trip traveler information website, and a traveler information phone system, to mitigate for construction effects and provide traveler information. The user defined the project in IDAS by indicating the location and number of CCTV cameras, the roadways and limits that would be covered by the traveler information system, and the way information was relayed to travelers (*17)*.

IDAS computes monetized travel time reliability for traveler information systems. The tool performs a traffic assignment for the control alternative and computes the delay time for the links covered by traveler information systems (*17*). IDAS calculates delay time through differences in the loaded travel time and the free flow travel time. The travel reliability module uses the calculated delay time to estimate the overall person-hours saved, translated into user-mobility benefits (*17)*.

IH 89 Advanced Traffic Management System either deployed CCTV cameras, RTMS, or both for traffic detection along with variable message sings (VMS) to provide freeway monitoring and incident management capabilities. IDAS defined the project by indicating the location and number of CCTV cameras and freeway links that would equip with freeway monitoring and incident management capabilities (*17*). As noted previously, most travel demand models do not account for non-recurrent congestion. IDAS quantifies the benefits of incident management by focusing on improvements in travel-time reliability instead of direct travel-time benefits from the reduction in incident duration between the base case and alternative scenario (*17*).

Both case studies show IDAS accounted for travel-time reliability through monetary values. The sensitivity analysis showed that the results for incident management systems are not very sensitive to changes in the percentage of reduction in incident duration, most likely attributed to travel-time reliability only being an approximate measure for estimating the benefits of incident management systems (*17*). Many of the default values for IDAS are since outdated as it was first developed to quantify the effects of operational strategies.

SIMULATION OR MULTIRESOLUTION METHODS

Incorporating Travel-Time Reliability into the Highway Capacity Manual (L08)

The L08 tool, heavily influenced by FHWA's Highway Capacity Manual (HCM), evaluates the travel time reliability along a corridor (*12*). The tool attempts to use traditional performance measures, such as travel time, vehicle delay, etc., with widespread non-recurring scenarios to understand the performance of a corridor over a year. L08 provides two different tools:

- **FREEVAL**: An open-source software developed by the Institute for Transportation Research and Education (ITRE) at North Carolina State University for freeway analysis to replicate traffic patterns present on these roadways. This tool incorporates the HCM freeway facilities method, for basic freeway segments, weaving segments, and merge and diverge segments (*18*). FREEVAL requires two inputs—corridor geometry and hourly demand—but additional inputs can be submitted to account for nonrecurring delay.
- **STREETVAL**: While like FREEVAL, STREETVAL, analyzes urban signalized corridors. It uses roadway geometry like the FREEVAL module but requires peak hour turning volumes and signal timing information and allows for inputs of nonrecurring delay.

MnDOT tested the tool through the case studies documented below.

Westbound IH 494 Auxiliary Lane from IH 35W to France Avenue (FREEVAL)

In 2013, MnDOT completed a capacity expansion project on westbound IH 494 to help address the large traffic volumes headed to the southwest metropolitan area of Minneapolis-St. Paul. Before the project, this corridor experienced over seven hours of daily congested speeds during the morning and evening peaks. Researchers selected this project as a candidate to assess the applicability and accuracy of the tool because of the available before and after data.

Researchers evaluated build and no-build scenarios during the morning and evening peaks and showed a significant reduction in recurring and nonrecurring delay completing the project (*10*). To verify this finding, researchers evaluated a second procedure using the SHPR 2 L02 process. This process evaluated the empirical annual corridor delay through vehicle-miles travel and travel time information from loop detector data (*10*). The L02 empirical process found the tool underestimated recurring delay by a factor of two for both periods. In the future, a more strenuous analysis to calibrate the tool could help close the gap between the two procedures.

TH 65 Conversion to Superstreet (STREETVAL)

Trunk Highway 65 (TH 65), a principal arterial located in the Twin Cities, experiences significant levels of commuter traffic causing delay at several signalized intersections (*10*). The design seeks to mitigate this by converting traditional signalized intersections to reduced-conflict intersections (RCIs) (also known as a superstreet), preventing left-turning movements from minor approaches by redirecting them to right-turns and allowing U-turn movements downstream (*10*).

Researchers analyzed a build and no-build scenario and the L08 tool estimated a marginal decrease in average travel time per vehicle and a marginal increase in average speed. The L08 tool estimated a large decrease in total delay hours and further evaluated through a secondary simulation software package. The decrease in total delay hours output by the second model were only a third of those generated by the L08 model, illustrating an overestimation of total delay benefits.

TH 252 Conversion to Freeway (FREEVAL and STREETVAL)

Researchers conducted an arterial-to-freeway conversion study for TH 252, a principal arterial located in the northwestern suburbs of the Twin Cities. Since the project entailed an evaluation of a signalized arterial and a freeway, researchers used both the FREEVAL and STREETVAL modules. To understand the impacts of converting the arterial into a freeway, researchers developed no-build and build scenarios through the year 2040. The tool showed the build scenario would significantly reduce travel time from 29 minutes to 11 minutes through the study corridor (*10*). Each scenario conducted a visual assessment of reliability based on the spread of travel times. The tool concluded that users can expect greater dependability on their anticipated commute times under the build scenario during the evening peak (*10*). Traffic values from INRIX before project implementation were compared to those the tool computed.

MnDOT concluded that differences in FREEVAL-RL and STREETVAL evaluation methodologies would slightly impact the results, and researchers determined that FREEVAL-RL may be more reflective of drivers' experiences as, "it more accurately replicates the travel time distribution experienced for all users, rather than just one user in each time period" (*10*).

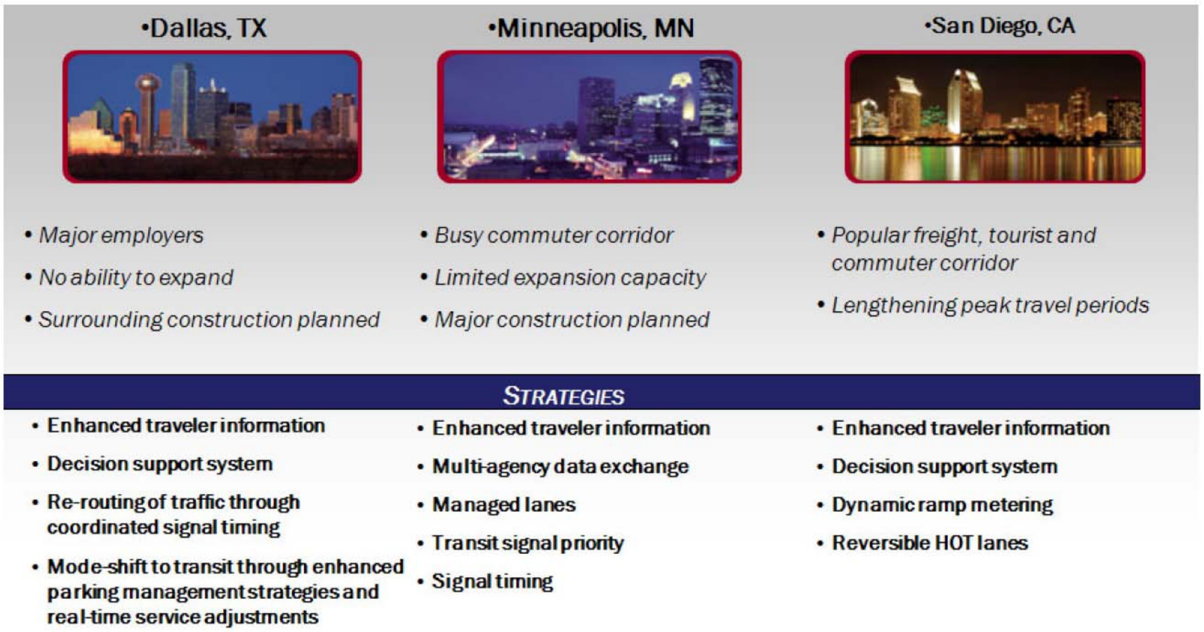
Conclusion about Case Studies for L08

One of the primary benefits of the L08 tool is the comprehensive presence of the HCM methodology. MnDOT may use FREEVAL-RL as an analysis tool rather than the conventional FREEVAL due to its ability to perform the evaluation under base conditions (*10*). MnDOT needs further investigation and validation to determine the applicability of STREETVAL to corridor-level operations.

Integrated Corridor Management Modeling in Dallas, Minneapolis, and San Diego

Integrated Corridor Management (ICM) is the integrated management of freeway, transit, arterial, and parking systems within a corridor using ITS technologies and innovative practices (*19*). FHWA selected eight pioneer sites in 2005; three underwent analysis, modeling, and simulation to understand the effect of ICM strategies such as ramp metering, congestion pricing, signal optimization, transit priority, and enhanced traveler information on mobility, reliability, and environmental impacts of the entire transportation corridor (*20*). Exhibit 9 provides an overview of the location and factors of the three tested sites.

Exhibit 9. Overview of the Three Pioneer Sites (*20*)



[Source: Research and Innovative Technologies Administration, ITS JPO.]

To understand the effects of each of the strategies, researchers tested various scenarios that included non-recurrent congestion triggers and various levels of travel demand during recurrent traffic conditions. The comprehensive methodology tested beyond specific elements of a corridor to various operational conditions across times and modes (Exhibit 10) (*20*).

Exhibit 10. Overview of Methodology to Test ICM Approach (*20*)

The methodology understands the system at specific corridor levels:

- **Macroscopic**: Regional level analysis looking at overall trip patterns.
- **Mesoscopic**: Individual driver behavior effected by implemented strategies.
- **Microscopic**: Impact of traffic control strategies at roadway intersection and interchanges.

Each of these levels were analyzed from a baseline and future year. The baseline year data served as a mechanism to compare the true effect of the strategies. The tool test five groups of performance measures (*20*):

- **Mobility**: The efficiency of the movement of people and freight in a corridor including travel time, delay, and throughput. An estimation of the impact of ICM on reducing extreme travel times was compared to the percentage of trips under the same threshold travel time in pre-and post-ICM scenarios
- **Reliability and Variability of Travel Time**: The relative predictability of the public's travel time and how mobility varied each day, measured by the Planning Time Index and changes in standard deviation. The Planning Time Index is the extra time (time cushion) that travelers must add to their average travel time when planning trips to ensure on-time arrival; on-time arrive assumes the 95th percentile of travel time distribution.
- **Emissions**: Impact of ICM strategies on toxic emissions, including variables such as facility type, vehicle mix, and travel speed.
- **Fuel Consumption**: Impact of ICM strategies on fuel consumption, including variables such as facility type, vehicle mix, and travel speed.
- **Benefits and Cost Comparison**: Effectiveness of investment of strategy relative to the cost.

After running the models, saved travel time, increased travel time reliability, reduced fuel consumption, and reduced emissions production were all monetized to provide a comparison to the investment of the ICM system. Researchers calculated the benefits on a facility basis by summarizing the person miles traveled (PMT) and person hours traveled (PHT) on individual links to understand the overall benefit to the network system (*20*). The model showed that ICM benefited the overall corridor performance through (Exhibit 11) (*20*):

- **Improved mobility**: All three sites showed travel times improved nearly tenfold under conditions of high demand and severe traffic incident.
- **Improved reliability**: Improvement of the transportation corridor ranged from 2 to 23 percent under all operation scenarios evaluated. Areas with more stable congestion levels did not see as much of an improvement as those with more extreme congestion—an indication that the strategies had a bigger impact on non-recurring congestion.
- **More extensive use of excess transit capacity**: Two of the sites planned to expand transit parking, and the model indicated the ability for increasing transit utilization specifically under incident conditions.
- **Reduced toxic emissions and fuel consumption**: The model indicated all three sites would see this benefit with Dallas estimated to see the greatest savings due to its extensive transit options; San Diego followed second.

Exhibit 11. Expected Benefits on the Corridor based on the Model (*20*)

PERFORMANCE MEASURE AREAS	San Diego	Dallas	Minneapolis
Annual Travel Time Savings (Person-Hours)	246,000	740,000	132,000
Improvement in Travel-Time Reliability (Reduction in Travel-Time Variance)	10.6%	3%	4.4%
Fuel Saved Annually (in Gallons)	323,000	981,000	17,600
Tons of Mobile Emissions Saved Annually (in Tons)	3,100	9,400	175

While the model does not perfectly depict conditions, it showed that overall reliability would improve with the implementation of ICM strategies. As previously noted, not all ICM strategies will provide the same benefit in different geographic regions. It is important to still understand the overall region to better identify the best strategies. Overall, the model did suggest that ICM provides greater benefit to areas that are more heavily congested and is even more important under conditions of severe traffic incidents (non-recurring congestion).

CASE STUDIES – PROJECT IMPLEMENTATION

Case studies provide a guide for agencies to incorporate reliability metrics into project implementation and discover new lessons learned.

Assessing Longitudinal Arterial Performance and Traffic Signal Retiming Outcomes

Active traffic management, traffic signal retiming tool, often goes unnoticed in the amount of benefits it can provide to reduce congestion. A five-year study assessed the impacts of retiming signals using these primary performance measures (*21*):

- **Percentage of arrival on greens** (The percentage of vehicles that hit a green light out of the total amount of vehicles who pass through the signal).
- **Planning Time Index.**
- **Travel Time Index.**
- **Average Travel Time.**

Researchers studied a road segment on SR 37 in Indiana for over 5 years to understand the effects of signal retiming. The signals were retimed three times in 2010, 2013, and 2015 by analyzing high resolution data and using a function designed to maximize arrival on greens.

The estimated savings from the implementation of ATM in traffic signal retiming and the return on investment costs helped researchers conclude that an active approach to signal retiming would help prevent degradation of traffic conditions near the signals (*21*). The research suggested retiming signals every two years, if not annually. In addition to retiming, high resolution data should supplement the strategy for accurate evaluation of the signal.

Isolated Versus Coordinated Ramp Metering

Researchers in Paris explored the effects of various ramp metering methods (controlling the flow of traffic entering a freeway) on roadway congestion and reliability. These methods included ***(Error! Bookmark not defined.)***:

- **No-Control**
  - No ramp metering.
- **ALINEA – Isolated Traffic Response Strategy**
  - Maintains the flow of traffic downstream from the ramp by monitoring downstream measurements.
  - Does not require the collection of active on-ramp measurements as it only accounts for downstream highway congestion levels
- **CORDIN – Coordinated Control Strategy**
  - The main philosophy consists "of using free up-stream on-ramp capacities in case of downstream motorway congestion*".*
  - Require active on-ramp measurements.

The use of ramp metering resulted in a 24 to 37 percent increase in reliability for both the ALINEA and CORDIN methods when compared to the no-control case *(5).*

Additional Benefits from the active ramp metering strategies included:

- A decrease in the spread of variation of travel times for both ALINEA and CORDIN, indicating that trip times became more reliable.

- The Misery Index (MI) (the comparison of 20th percentile of travel times to the median travel times) saw large decreases for both ramp metering strategies.
- The percentage of roadway users experiencing more than 10 minutes of delay decreased for the ALINEA method (from 28 to 18 percent).

Researchers concluded travel time reliability is easily included into project assessment "without any significant difficulties" (*5*). Travel time reliability is an increasingly important project benefit measure. Researchers noted that both ramp metering strategies impacted travel time reliability the same, but the CORDIN method reduced total travel time more (*5*). Ultimately the active study illustrates the ease of incorporating reliability metrics into project evaluation and the effectiveness of active ramp metering on traffic.

Seattle/Lake Washington Corridor Urban Partnership Agreement

The Urban Partnership agreement analyzed reliability benefits on roadways in the Seattle/Lake Washington corridor as a result implementing ATM and ITS techniques to mitigate congestion. While researchers focused on the SR 520 corridor, they also observed the surrounding roads to determine any secondary effects the mitigation strategies might cause.

The project drew mixed conclusions, as targeted roadways saw decreases in the buffer index (corresponding to better reliability) unlike improvements in reliability. Increased reliability was only seen in certain directions and at peak travel periods (*22*).

CONCLUSIONS

Reliability does not discriminate against road user, affecting auto commuters, transit riders, and freight shippers. Some industries and travelers may place a higher value on reliability, but the concept remains important to ensuring people get to their destination safely and on-time.

While numerous tools evaluate reliability there is still the lack of confidence in these tools to incorporate reliability into the decision-making process. Agencies continue to use their reliability lenses but need assistance understanding project effects before implementation, a need sketch planning tools can meet. Understanding the effects of reliability by conducting case studies helps researchers better adopt tools that truly encompass the impact of project implementation on reliability.

This tech memo provided a comprehensive list of sketch-planning tools along with others that incorporate reliability into identifying projects and into their transportation planning process. It also included resources for other tools that help with understanding the effects projects have on reliability.

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