Metropolitan Highway System Investment Study

Final Report

PARSONS BRINCKERHOFF

September 2010

FINAL REPORT

Metropolitan Highway System Investment Study

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FIGURES

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Executive Summary

The 2030 Regional Transportation Policy Plan (TPP, adopted in 2009) provides a context for upcoming mobility and accessibility challenges in the Twin Cities from the year 2000: population growth of 966,000, employment growth of 520,000, and absent structural changes to transportation energy and infrastructure, daily increase of 15.3 million vehicle miles traveled (VMT). Recognizing no growing metropolitan area in the U.S. is able to build their way out of congestion, the Metropolitan Council (MetCouncil) and Minnesota Department of Transportation (Mn/DOT), through this effort and subsequent incorporation within the 2030 TPP, Statewide Transportation Plan (STP), and Mn/DOT Metro District Highway Investment Plan, endeavor to develop a future transportation investment strategy that optimizes the investments already made in the region through the use of multimodal-oriented managed lanes and comprehensive system management strategies. The consideration of managed lane elements provides an opportunity for travelers to opt their way out of congestion, even if system congestion may persist.

The Metropolitan Highway System Investment Study (MHSIS) is a contributing input to the 2030 Regional Transportation Policy Plan adopted in 2009. Similar efforts conducted by Mn/DOT and the Metropolitan Council in recent years (such as the 2009 Congestion Mitigation and Safety Plan, CMSP) have focused upon particular transportation policies in order to advance the TPP master plan. In the case of the MHSIS, this focus was the use of management strategies as a possible alternative for costly general purpose capacity expansion in the TPP. The MHSIS concentrated upon how active traffic management (ATM) and managed lane components could be combined and implemented in the Twin Cities. The purpose of these strategies is not to fix congestion, but rather to provide residents, employees, and visitors with a consistently congestion-free alternative throughout the regional highway system. Although other management strategies were initially considered in the MHSIS, such as access management and interchange consolidation, as these strategies did not further the primary purpose of providing a congestion-free alternative, these strategies (and the facilities upon which they were considered) were transferred to the CMSP and are not a component of this report.

Managed Lanes

Managed lanes have been in existence for nearly 30 years and represent a family of operational strategies designed to address a wide array of transportation goals. Managed lanes have a distinct advantage over general purpose lanes: through eligibility, access control, and pricing, managed lanes can provide for regular and predictable free-flow travel speeds on the managed lanes. In turn, free-flow managed lanes avoid traffic saturated general purpose lanes, yielding not only improved vehicular throughput in saturated conditions, but also improved person throughput based upon the encouragement (through price signals) of higher vehicle occupancies and bus ridership.

A variety of managed lane configurations are available for corridor-wide projects. The MHSIS concentrated upon those that have the likeliest application for the broadest number of facilities in the Minneapolis / St. Paul area. One of the principal objectives of the MHSIS was to identify how new managed capacity could be provided with higher value and less cost. To meet this objective, the MHSIS considered the deployment of managed lanes in the context of dedicated and dynamic shoulder use. As successfully demonstrated on the I-35W corridor, new managed lanes can be safely implemented with an alternative design to established managed lanes.

Active Traffic Management

Although ATM may be successfully implemented in an arterial corridor, ATM in this study provides for operating conditions that enable complete use of a freeway corridor's pavement, an important component of the MHSIS. ATM does this by dynamically managing traffic flow and lane assignment based on prevailing traffic conditions and presence of collisions or other incidents. ATM has been defined by Mn/DOT as including ITS strategies which may be implemented on non-freeway arterials, including strategies such as signal coordination, cameras for incident and traffic management, and changeable messaging signs. However, for the purpose of this analysis, ATM has been confined to freeway systems with the specific components identified below.

Focusing on trip reliability, its goal is to maximize the effectiveness and efficiency of the facility under recurring congestion and non-recurring incidents or road work. Through the flexible use of the roadway, it aims to increase system performance as well as traveler throughput and safety through the use of strategies that actively regulate the flow of traffic on a facility to match current operating conditions.

Study Process

In preparing and conducting the MHSIS, the project team first assembled information on peer communities, to determine how other metropolitan areas are evaluating the efficacy of management and operations strategies in the context of their long range plans. The findings from this assessment were used to inform the development of the MHSIS analysis. From this exercise, the project team prepared the performance measures for the MHSIS modeling activities. Findings from the evaluation of specific projects provide detailed findings for each project identified in the MHSIS draft plan. Additionally, econometric analyses were conducted for managed lane projects as well as for ATM implementation. As ATM will likely be a necessary complementary strategy to managed lanes in order to mitigate concerns when using shoulder lanes, this analysis is conducted concurrent to the capacity analysis. Finally, phasing and other conclusions for incorporation within the 2030 TPP was examined.

Four categories of performance measures were used to examine the MHSIS alternatives:

- Increase the person-moving capability of the metropolitan highway system
- Manage and optimize, to the greatest extent possible, the existing system
- Reduce future demand on the highway system
- Implement strategic and affordable investments

MHSIS Project Evaluation

Initially, a total of 41 separate projects were identified for analysis in the MHSIS. Thirty-four of these projects were developed by the MHSIS Project Management Team (PMT), comprised of Mn/DOT and MetCouncil representatives, prior to the conduct of the MHSIS study. Seven additional facilities were added to the MHSIS analysis based upon preliminary study corridors identified by the MnPass System Study Phase 2. These projects included managed lane expansion projects (building a new concurrent flow managed lane), managed lane conversion projects (adapting an existing general purpose lane into managed lane operations), interchange closure, multiple interchange consolidation, limited access design conversion, strategic capacity expansion, and expressway expansion. However, as the MHSIS PMT focused the MHSIS analysis upon managed lanes, the other strategy elements were placed within the purview of other efforts – including the Congestion Mitigation and Safety Program (CMSP), 2030 TPP Update, and related planning. Finally, during the course of the MHSIS, Mn/DOT conducted an update to the MnPass System Study, which adopted a policy of managed lane expansion only. Given the desire for concurrence and performance metrics which indicated a preference for expansion over conversion, only managed lane expansions were forwarded for analysis in this Final Report (full analysis of the conversion projects may be found in the technical appendices).

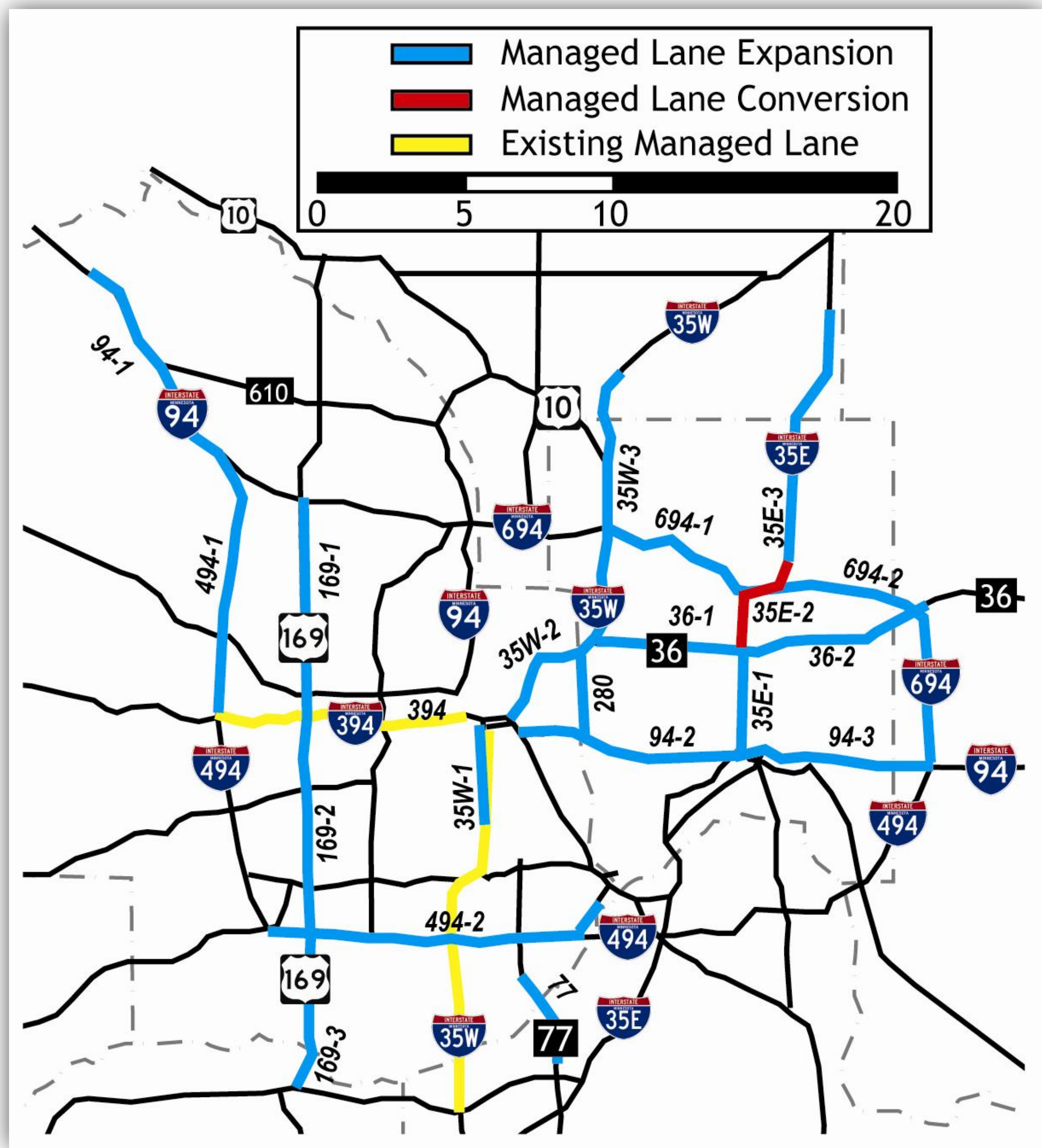


FIGURE 1: MANAGED LANE UNIVERSE OF PROJECTS

The MHSIS Study was completed concurrently with the MnPass System Study Phase 2. Although these studies were conducted with different objectives and timeframes for analysis, the measurements used for cost were mirrored closely between the two studies; however there are four primary areas where the MHSIS study differed from the MnPass Study. First, the MHSIS did not include any cost for direct connections between managed lane facilities; however, the MnPass System Study Phase 2 did look into the geometrics and cost for how a managed left lane structure would connect into the downtown exits. As the presence of direct connection was not included in the performance modeling, these costs are excluded from the MHSIS. However, the benefit of the connections has been evaluated as a part of the MnPass System Study Phase 2 and should be considered valid for correlation to MHSIS projects. Second, the MHSIS applied a lower miscellaneous cost for the corridors, but was balanced out by the risk factors. The MnPass System Study Phase 2 applied the same risk factor to the low and high range. In contrast, the MHSIS used risks that varied by 10% between the low and high ranges. Third, the MnPass System Study Phase 2's timeframe for analysis was 2-10 years, with a keystone analysis of year 2015, whereas the MHSIS used a 20-year timeframe with the year 2030 as the keystone. Finally, the study corridors did not perfectly align between both studies. As a result, segment consideration may drive differences between the MnPass and MHSIS study corridors.

One of the main recommendations of the MHSIS is for the continued communication and coordination between the agencies on implementation of the desired project concurrently with the preservation of other maintenance or design projects. Examples of these situations could vary from an existing bridge that is programmed for replacement or a standard mill and overlay preservation project to a strategic capacity enhancement that would perform even better with additional ATMs.

Analytical Findings

In the Table 1 and Figure 2 summary, the overall performance rating of the managed lane corridors indicate which improvements best correspond with the objectives of the MHSIS for assumed potential implementation by 2030. Corridors with a rating of "High" or "Moderate" are likely in keeping with the guiding principles of the MHSIS. By contrast, those with a "Low" rating may not correspond from a performance perspective. Although some facilities may not be appropriate for the short term (2030), these managed lanes may work for the longer term (2030 – 2060), and as a result remain within the long-term vision of the managed lane network for the region.

TABLE 1: MANAGED LANE PRIORITIZATION SUMMARY

Corridor	Throughput	Optimization	Demand Reduction	Cost Effectiveness	Transit Suitability	Investment Parity	Opportunity	Composite
169-2	Moderate	Moderate	Moderate	Low	High	Moderate	High	**Moderate**
169-3	High	Moderate	Moderate	Low	Moderate	High	High	**Moderate**
35E-1	High	Low	Low	Moderate	Moderate	High	High	**High**
35E-2	Moderate	Low	Moderate	High	Low	Low	Moderate	**Moderate**
35E-3	Moderate	Moderate	Moderate	Moderate	Low	Moderate	Moderate	**Low**
35W-1	Low	Moderate	Moderate	Moderate	High	High	High	**High**
35W-2	High	Low	Moderate	Moderate	High	Moderate	Moderate	**Moderate**
35W-3	Moderate	Moderate	Moderate	Moderate	High	Moderate	High	**High**
36-1	Moderate	Moderate	Moderate	High	High	High	High	**High**
36-2	Low	Moderate	Moderate	High	High	Low	High	**Moderate**
494-1	Moderate	Moderate	High	Moderate	Low	High	Low	**Moderate**
494-2	Moderate	Moderate	Low	Low	Low	Moderate	Low	**Low**
694-1	High	Low	High	Moderate	Low	High	High	**High**
694-2	Moderate	Moderate	Moderate	Low	Low	High	Low	**Low**
77	High	Low	Low	Low	High	Moderate	High	**Moderate**
94-1	Low	High	High	Moderate	Moderate	Moderate	Moderate	**Moderate**
94-2	High	Low	Moderate	Low	High	Moderate	High	**Moderate**
94-3	Low	Low	Low	Low	High	Moderate	Moderate	**Low**

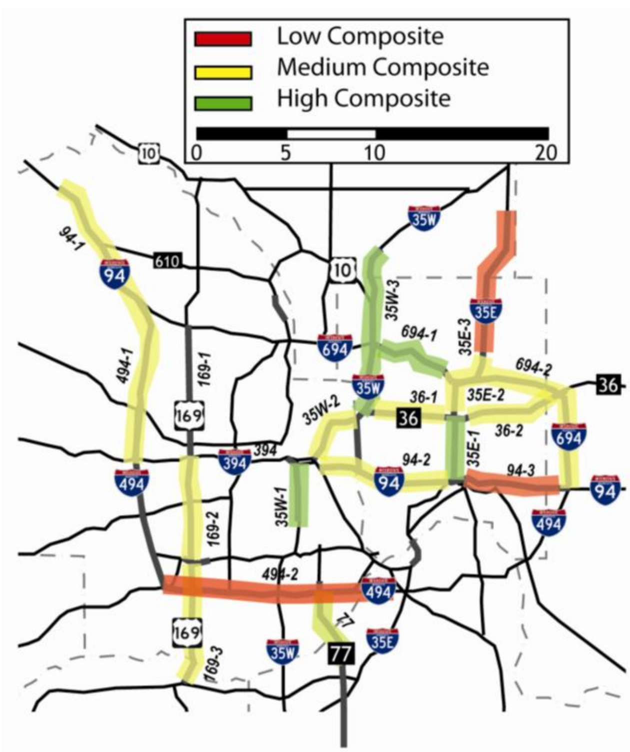


FIGURE 2: MANAGED LANE PRIORITIZATION SUMMARY

2030 MANAGED LANES PLAN

Of capacity expansion projects, certain managed lane projects stand-out as advantageous for action within the 2010 – 2030 timeframe:

- I-35E, from downtown St. Paul to north of I-694 (35E-1 and 35E-2). Although not as high a performer as other managed lane corridors, there are extenuating circumstances that advance this corridor. First, the Cayuga Bridge reconstruction project provides an opportunity to cost effectively add managed lanes. Furthermore, the reconstructed interchange at I-694 has abundant pavement availability, allowing for managed lane expansion in this segment without substantial additional cost. Together, this permits a greater return on investment from the reconstruction activities. Second, this section of the metropolitan highway system rates well for parity purposes (addressing previously planned facilities in the long range plan).

- I-494, from I-394 to I-94/I-494 interchange (494-1). The I-494 corridor would significantly benefit from the implementation of managed lanes, as evidenced from the modeling activities. Furthermore, this corridor has a high rating for investment parity, based upon prior commitments in the long range plan. Finally, the corridor helps the I-394 MnPass lanes constitute the beginning of a system, with the possibility to serve managed lane trips from the south to northwest Metro across much of the system. The key limitation of this corridor will be the likely lack of connectivity between the I-394 MnPass lanes and the I-494 managed lanes, although this could be addressed in the future if the interchange must be reconstructed. However, given the strength in performance and moderately rated cost effectiveness, this corridor's opportunities outweigh its weaknesses.

- I-35W, from downtown Minneapolis to 95th (35W-1 and 35W-2). I-35W north is one of the strongest transit corridors for the managed lane system, and deserves special consideration here. In addition to its transit suitability, this corridor has moderate-to-high ratings for performance, including throughput, optimization and SOV travel reduction. The ability to serve regional and inter-regional trips on the managed lane system is high, with close connections to I-394 and I-35W to the south. Finally, given the presence of existing bus-only-shoulder operations, the ability to convert this facility to managed lanes is strong.

- TH-36, between I-35E and I-35W (36-1). TH-36 held moderate ratings throughout all performance criteria. This segment also performs well for transit suitability, investment parity, and cost effectiveness. Finally, this segment is programmed for interchange work on Lexington and Rice, providing an efficiency opportunity to address managed lanes as it pertains to these structures. As a result, TH-36 is recommended for managed lanes development in the MHSIS. However, one crucial concern with TH-36 is its connections with I-35W an I-35E. Without direct connection ramps, which are cost prohibitive without appropriately sized accompanying benefit, the termini for TH-36 median-based managed lanes would require weaving to a right-side ramp in both conditions. In the case of westbound TH-36 to southbound I-35W, this movement would likely severely curtail corridor operations. Additional simulation study is recommended to determine the operational impacts of managed lanes on this corridor without direct connections. In the next 20 years, it may be possible to implement asynchronous managed lanes on this corridor, featuring an eastbound-only treatment. Again, additional study should evaluate the effectiveness of an asynchronous treatment if a bi-directional treatment cannot be affirmed.

- I-94, between downtown Minneapolis and downtown St. Paul (94-2). The I-94 managed lane project rated well for throughput, but low for optimization primarily due to the constraints imposed upon the corridor by the Lowry Hill tunnel and the Capitol interchange. Furthermore, the need to replace structures in the corridor yields an elevated cost versus other facilities in the region, thereby depressing the corridor's overall cost effectiveness rating. Pending deployment of ATM in the corridor may assist in addressing some of the corridor's traffic effects, while providing for enhanced bus operations. Furthermore, a parallel light rail transit facility will soon open, providing a corridor alternative for transit riders. All of these conditions lend to a conclusion that I-94 should remain a medium priority for managed lane development, with an understanding that upcoming opportunities may arise for reconstruction purposes that can positively affect the return on investment in this corridor.

The MHSIS Project Management Team has developed a working budget estimated at approximately $450 to $500 million (2010 dollars) for the years 2014 – 2020 for deployment on managed lane facilities, and an additional $50 to $100 million anticipated for ATM deployment. As ATM as a concept has been refined as a supplement to managed lane deployment, an independent budget may be counterproductive. The consolidated budget is estimated at approximately $500 to $600 million. As such, the following estimates include the deployment of ATM as a complementary strategy to managed lanes. Given managed lanes and ATM deployment share some infrastructure, the specific cost for ATM is reduced from $2.0 M per mile to $1.6 M per mile. Using cost estimates refined by the MnPass System Study Phase 2 for the early action corridors (where available), this yields a simple division of expenditure (2010 dollars) in Table 13.

TABLE 2: COST ESTIMATE BY 2030 MANAGED LANE CORRIDOR

Project	Construction ($M 2010)	ATM ($M 2010)	Total (inc. risk) ($M 2010)
I-35E	$75	$12	$120
I-494	50	11	61
I-35W	165	24	255
TH-36 (est. asynch.)	16	6	28
I-94	88	15	103
TOTAL	$ 394 M	$ 68 M	$ 567 M

Additional facilities that are recognized for the long-term (2030 – 2060 timeframe) implementation include:

- TH-77, between 141st Street and TH-62. The TH-77 corridor is currently under study by Mn/DOT for managed lane feasibility, with a planned Bus Rapid Transit lane to be constructed in the vicinity of the Apple Valley Transit Center in the next few years. Although the performance modeling did not rate favorably for the corridor, this is due to the length of the modeled facility. Current planning activities indicate a shorter segment may be feasible and meet project needs. In order to avoid biasing the results of this planning study, the MHSIS is avoiding a prioritized determination of feasibility for 2030, but has included the facility for planning purposes.

- I-94, between TH-101 and I-494 (94-1). The market for this project may be significantly affected by the completion of TH-610. Managed lane implementation may be warranted in the future, but 2030 performance metrics indicate the usefulness of managed lanes for person throughput may be constrained. It is recommended to evaluate the efficacy of this project as an extension of I-494 managed lanes (upon deployment) and post-completion of TH-610.

- I-694, between I-35E and I-35W (694-1). The I-694 segment between I-35W and I-35E rates highly for performance metrics, including throughput and SOV demand reduction. Additionally, this corridor rates well for investment parity purposes, based upon previous commitments in the 2030 plan, and rates moderately well for cost effectiveness. The benefit-cost calculation, though, did not account for programmed improvements to the I-35W / I-694 interchange as well as additional investment on I-694 in this segment. As a result, this cooperative opportunity would benefit the implementation of managed lanes in this segment. Additional study should assess the specific value of bi-directional and asynchronous (westbound only) treatments, especially in light of potential asynchronous treatment on TH-36 in the opposing direction.

- US 169, between TH-62 and the Minnesota River (169-3). Managed lanes on US 169 offer moderately strong performance metrics, but poor cost effectiveness due to the limited market for this facility relative to cost. As population expands in the southwest Twin Cities, this facility may become more necessary in order to enhance mobility options from the growth sectors to the urbanized area. Planned improvements to the I-494 and US 169 interchange provide an opportunity to reduce the cost of development of managed lanes. At a minimum, it is recommended that this interchange effort consider the future implementation of managed lanes on not only US 169, but also I-494 in the design of the facility.

- US 169, between TH-62 and I-394 (169-2). If an opportunity for cost reduction is available for US 169 in this segment, the performance metrics suggest a productive corridor for managed lanes. Key questions concern the connectivity between I-394 and I-494. Without an opportunity for cost reduction, this project is not recommended for the 50-year horizon.

- I-494, between I-394 and Minneapolis / St. Paul airport (494-2). Whereas I-494 in the vicinity of I-35W has been designated as a potential strategic capacity expansion, it may be more productive to consider this segment as a managed lane corridor and extending the facility to MSP airport, which has acceptable performance metrics. However, given the high cost of this project, only an opportunistic perspective should be use for long-term development.

- TH-36, between I-35W and I-694 (36-1 and 36-2). Assuming TH-36 has an asynchronous development in the 20-year plan, the 50-year horizon suggests a bidirectional deployment may be warranted if connections to I-35W and I-35E can be resolved. Additionally, opportunities to extend the managed lane corridor to I-694 may be viewed favorably based upon performance estimates. This should be viewed opportunistically for cost reduction.

- I-694, between I-94 and I-35E (694-2). This segment of I-694 had moderate levels of performance benefit associated with managed lanes; however, the cost of development yielded low cost effectiveness relative to those benefits. As a result, the region should review this corridor in the perspective of opportunity for cost reduction.

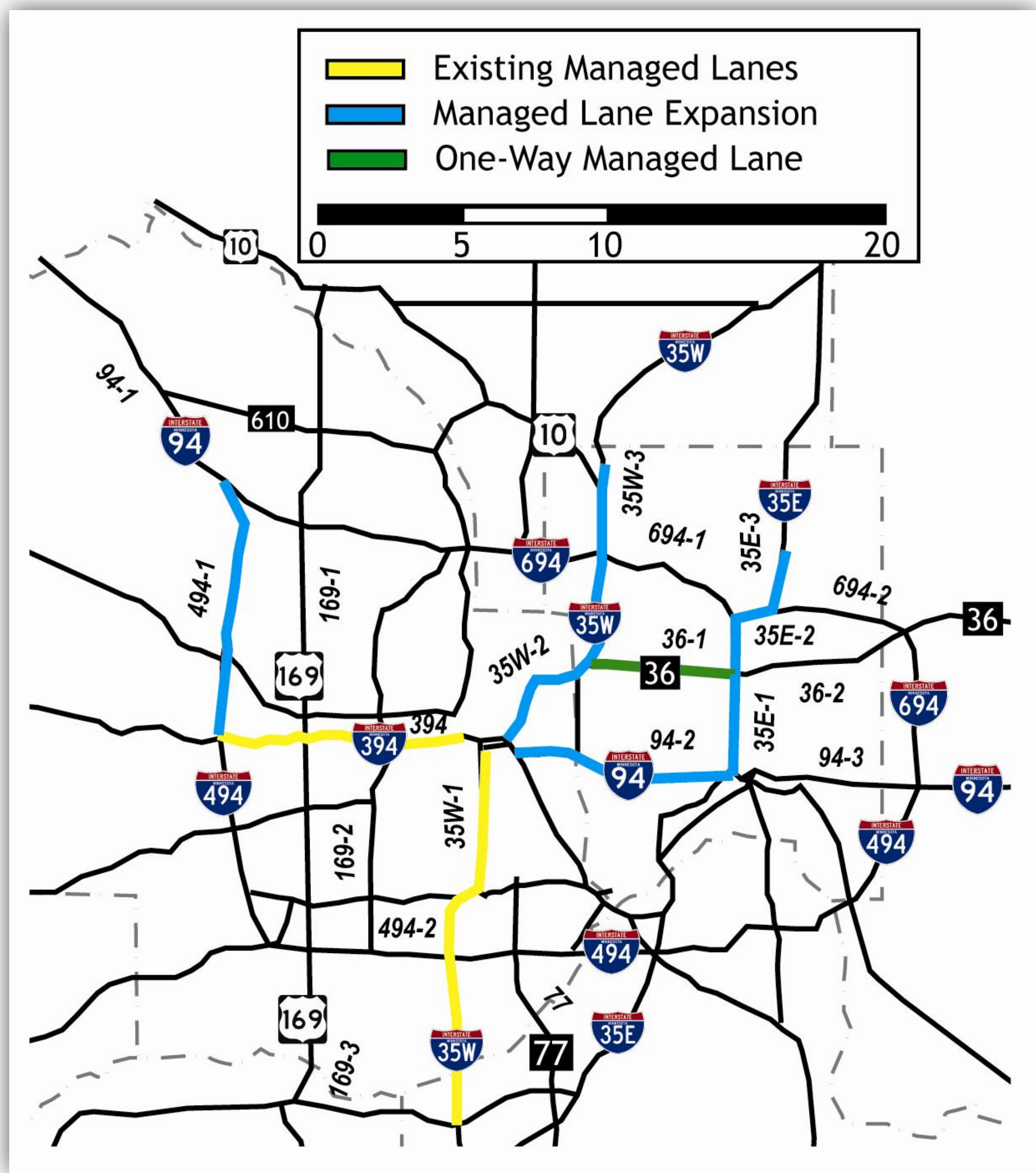


FIGURE 3: 20-YEAR MANAGED CAPACITY RECOMMENDED PROJECTS

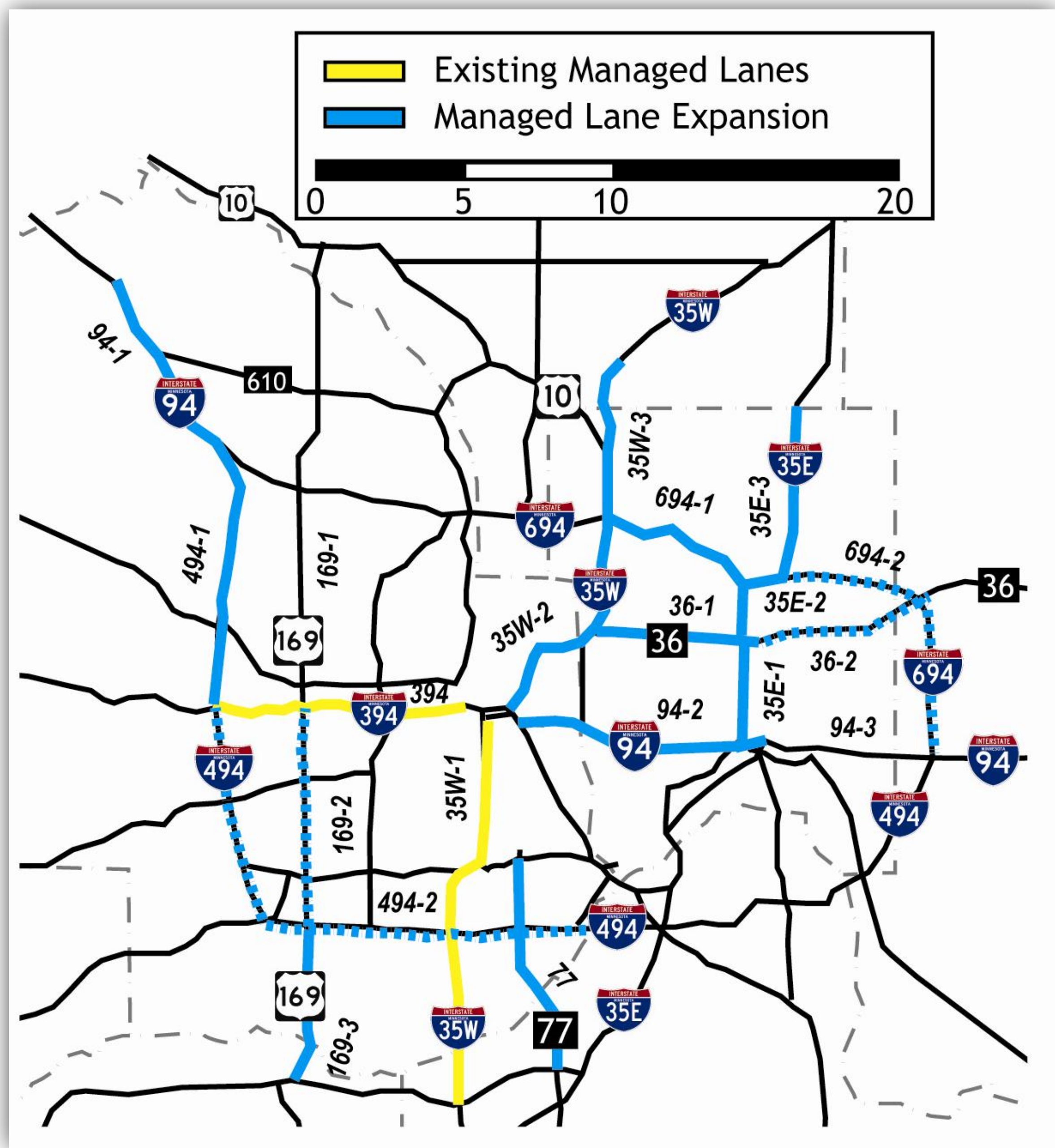


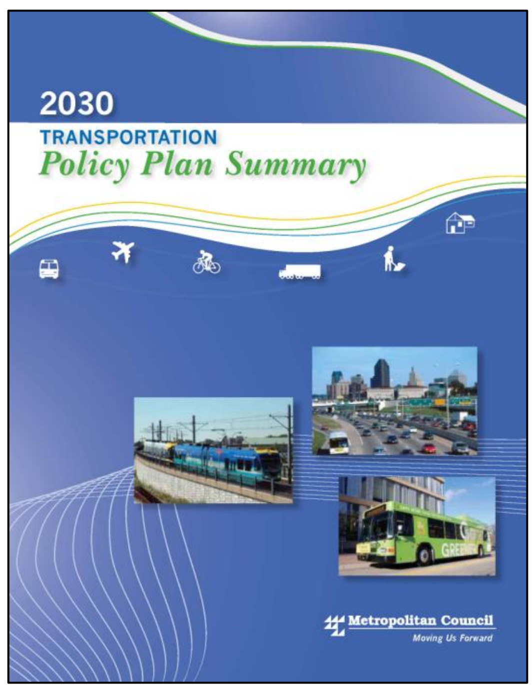
FIGURE 4: 50-YEAR MANAGED CAPACITY RECOMMENDED PROJECTS

1.0 INTRODUCTION

The need for timely, essential transportation infrastructure rehabilitation and development is apparent. According to the Texas Transportation Institute's 2009 Urban Mobility Study, annual hours of delay per peak traveler in the Minneapolis / St. Paul area has increased from 6 hours in 1982 to 39 hours in 2007 – an increase of 650 percent. Approximately 60 percent of Twin Cities peak period vehicle-miles of travel is now congested. As the effect of congestion upon Twin Cities person hours of delay (55 million hours in 2007) and fuel consumption (39 million gallons of wasted fuel) compound the impacts upon other economic measures (delivery times, unproductive labor time, business relocations, ineffective recruitment and retention, etc.), advancing viable congestion-relief projects across all modes of travel has become essential.

The 2030 Regional Transportation Policy Plan (TPP, adopted in 2009) provides a context for upcoming mobility and accessibility challenges in the Twin Cities from the year 2000: population growth of 966,000, employment growth of 520,000, and absent structural changes to transportation energy and infrastructure, daily increase of 15.3 million vehicle miles traveled (VMT). This constitutes, respectively, a 37 percent increase in population, 32 percent increase in employment, and 58 percent increase in VMT. In short, the existing transportation network will be challenged to accommodate this increase without consideration of more active management of the system. Furthermore, the 2007 Principal Arterial Study indicated approximately $40 billion would be needed in this timeframe to eliminate congestion on the network, a number that easily dwarfs the anticipated $6 billion in revenue to the Metropolitan area for the same time period (with only $900 million designated for capacity and safety enhancements).

Recognizing no growing metropolitan area in the U.S. is able to build their way out of congestion, the Metropolitan Council (MetCouncil) and Minnesota Department of Transportation (Mn/DOT), through this effort and subsequent incorporation within the 2030 TPP, Statewide Transportation Plan (STP), and Mn/DOT Metro District Highway Investment Plan, endeavor to develop a future transportation investment strategy that optimizes the investments already made in the region through the use of multimodal-oriented managed lanes and comprehensive system management strategies. As will be shown in this study, the consideration of management strategies and managed lane elements provides an opportunity for travelers to opt their way out of congestion, even if system congestion may persist.



The 2030 TPP recommends strategies that provide alternatives to single occupant vehicle (SOV) travel, targeted capacity mitigation where it will be the most effective in reducing congestion and a re-assessment of current highway expansion plans in terms of cost effectiveness and financial and implementation feasibility. The need for these strategies guided this study. The end result, to be described here, is the infusion of managed lane system concepts into the long-range transportation planning process.

Purpose of the MHSIS

The Metropolitan Highway System Investment Study (MHSIS) is a contributing input to the 2030 Regional Transportation Policy Plan adopted in 2009. Similar efforts conducted by Mn/DOT and the Metropolitan Council in recent years (such as the 2009 Congestion Mitigation and Safety Plan, CMSP) have focused upon particular transportation policies in order to advance the TPP master plan. In the case of the MHSIS, this focus was the use of management strategies as a possible alternative for costly general purpose capacity expansion in the TPP.

The MHSIS Project Management Team, comprised of Mn/DOT and Metropolitan Council staff, with Steering Committee concurrence, provided the project team with the guiding principles for the MHSIS study and evaluation. These guiding principles are as follows:

- *Utilize the most cost-effective operational and management techniques to optimize system performance*.
- *Managed lanes are a higher priority for improvement than general purpose lanes.*
- *There are some areas where traditional capacity will not be added; this does not preclude management, operational and pricing solutions.*
- *Needed segments of general purpose lanes may be converted to managed lanes*.
- *Highway improvements should enhance and support transit use where existing or planned express transit service exists.*
- *Flexible design may be needed to accommodate an improvement or project within the existing right-of-way. Overall safety must be maintained or improved.*
- *Complete the six-lane beltway and unfinished connections to utilize existing and planned investments*.
- *Do not add inbound capacity outside the beltway that cannot be accommodated by projects or operational changes/strategies on, or within, the beltway*.
- *Manage access to Interregional Corridors (IRC's) and other Principal Arterials*.
- *Asymmetrical improvements may be considered*.

Various efforts have been conducted throughout the past two decades that lead the Twin Cities toward an operations and management mindset for the metropolitan highway system. Transportation Demand Management (TDM), Transportation System Management (TSM), and Intelligent Transportation Systems (ITS) treatments are intended to mitigate traffic congestion and improve traffic safety, through introduction of lower-cost improvements that could be developed within the existing roadway right-of-way, thus avoiding the high right-of-way and construction costs associated with adding lanes on limited access highways to keep pace with traffic growth.

Recently, four strategies have received attention for their ability to enhance the return on investment in the Minneapolis / St. Paul region's transportation infrastructure. *Active Traffic Management* (ATM), as deployed on I-35W south of downtown Minneapolis and to be developed on I-94 between downtown St. Paul and downtown Minneapolis, denotes application of advanced electronics to assign traffic priority, lane assignment and speed/queue control, and includes such systems as ramp metering, speed harmonization, queue warning, and dynamic re-routing. *Managed Lanes* include provision of dedicated lanes for use by high-occupancy vehicles, trucks, or any vehicle willing to pay a price to use lanes which operate at a higher speed than adjacent general purpose lanes. *Use of Shoulders* involves either operating buses on roadway shoulders in slower speed application to bypass general purpose lane traffic queuing during peak periods (as on the existing freeway system in the Twin Cities) or using the shoulders for general traffic during peak periods to maintain or provide added capacity, potentially in conjunction with the application of managed lanes on the inside of the roadway. Finally, *Bus Rapid Transit* (BRT) includes the provision of enhanced express bus services and introduction of limited-stop service with on-line stops.

The MHSIS concentrated upon how these four principal components could be combined and implemented in the Twin Cities. The purpose of these strategies is not to fix congestion, but rather to provide residents, employees, and visitors with a consistently congestion-free alternative throughout the regional highway system. Managing one or more lanes of traffic for congestion-free conditions is the primary purpose of the strategies listed above. Although other management strategies were initially considered in the MHSIS, such as access management and interchange consolidation, as these strategies did not further the primary purpose of providing a congestion-free alternative, these strategies (and the facilities upon which they were considered) were transferred to the CMSP and are not a component of this report.

Study Area

The initial study area of the MHSIS was comprised of the counties of Hennepin, Ramsey, Carter, Anoka, Dakota, Scott, Carver, and Washington. However, as the focus of the MHSIS study through the guiding principles involved providing options for systemic congestion relief, the applied corridors concentrated upon the metropolitan core of these counties. Exterior counties, such as Wright county, may benefit from the implementation of management concepts in the metropolitan core; however, the baseline conditions for these strategies' success do not exist outside the metropolitan area, and as such, were not studied.

Types of Projects

The universe of projects initially comprised a broad range of transportation demand and system management strategies. The existing implementation of various system management strategies, such as extensive Intelligent Transportation Systems (ITS) and access management programs, allowed the MHSIS to focus upon those projects which directly addressed the core objective of providing a consistently congestion-free alternative on metropolitan highways. The primary strategy meeting this definition is managed lanes, with a complementary strategy of active traffic management.

Other strategies, such as access management, interchange consolidation, and interregional corridor designation were not addressed in the MHSIS final report, and may be considered in other contributing components to the 2030 Regional TPP.

MANAGED LANES

Managed lanes have been in existence for nearly 30 years and represent a family of operational strategies designed to address a wide array of transportation goals. The term itself is ambiguous and can mean different things to different stakeholders in the transportation industry. One key aspect that all managed lane facilities share in common is active demand and system management. Oftentimes, the development of managed lanes has come from the realization that high demand on existing facilities necessitates the efficient management of those facilities. This holds especially true in situations where options for constructing new capacity are limited. Latent demand in moderate to severely congested corridors can quickly fill added capacity that is not managed. Managed lanes, including those applied in Minnesota, typically comprise three principal elements:

- Eligibility. Eligibility refers to the restriction of certain vehicles and vehicle types from accessing a given facility, which is most often based on occupancy or vehicle type. Restrictions based on occupancy generally stipulate that only vehicles carrying a certain number of occupants – usually 2 or greater – may enter a facility for free. In the case of traditional HOV lanes, SOV's are barred completely from accessing such facilities, whereas in HOT lane applications, they are allowed to access facilities with the payment of a toll. Restrictions based on vehicle type generally bar certain types of vehicles from entering a facility, such as large commercial trucks, or provide free access for others, such as inherently low emission vehicles or motorcycles. Eligibility may also vary by time of day or change over the life of the facility in response to changing volumes of various vehicle classes. HOT lane facilities, for example, may experience growth in the volume of users such that congestion begins to occur and the level of service on the facility is degraded. In this case, a hierarchy of users is established, and eligibility requirements may be adjusted so as to price out lower priority users such as SOVs.
- Access Control. A common feature of managed lanes is the physical separation of vehicles on managed facilities from those on adjacent general purpose lanes. Access control is often accomplished by physically separating a managed lane facility from other facilities via barrier or buffer, such as those found on the portion of the I-394 MnPass lane east of TH-100. For managed lanes utilizing shoulders (such as I-35W's PDSL system), right of way may be insufficient to construct a barrier or buffer, and a simple stripe with supplemental signing has to suffice.
- Pricing. The pricing aspect of managed lanes refers to the use of price controls for the purposes of controlling volumes and generating revenue on managed lanes facilities. Managed lanes need not feature a pricing component. However, many recent facilities do include a pricing element that can be structured to accomplish a number of goals. Pricing may be fixed, with one flat rate being charged for all users during all times of the day; set on a variable schedule, where rates change pursuant to a pre-established schedule; or dynamic such as on I-394 and I-35W, where the price for access increases during times of day when volumes are the highest. Dynamic pricing entails adjusting the price for facility access in real time in relation to the vehicular volume on the facility. As the number of vehicles increases, so does the price. Currently, Mn/DOT's policy for pricing on the MnPass system is for demand management prioritization, with revenue generation only as a secondary consideration.

Managed lanes have a distinct advantage over general purpose lanes: through eligibility, access control, and pricing, managed lanes can provide for regular and predictable free-flow travel speeds on the managed lanes. In turn, free-flow managed lanes avoid traffic saturated general purpose lanes, yielding not only improved vehicular throughput in saturated conditions, but also improved person throughput based upon the encouragement (through price signals) of higher vehicle occupancies and bus ridership. Recent evidence as published in the *US DOT Congestion Pricing Primer* illustrates this advantage (Figure 5).

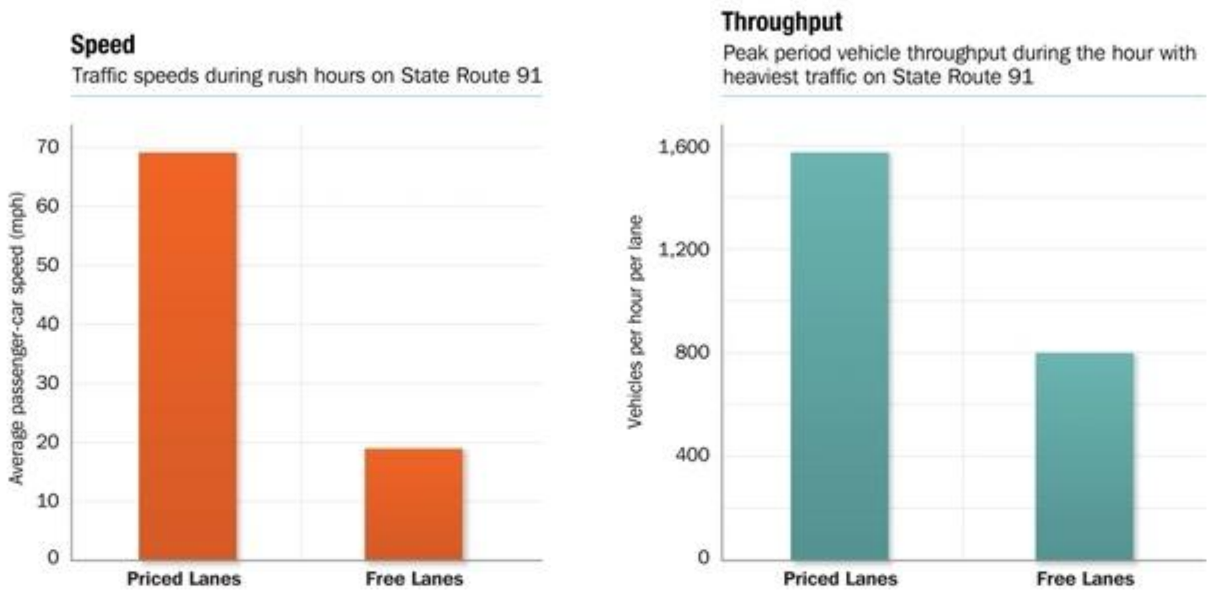


FIGURE 5: COMPARISON OF SPEED AND THROUGHPUT (MANAGED LANES VS. GENERAL PURPOSE LANES)

A variety of managed lane configurations are available for corridor-wide projects. The MHSIS concentrated upon those that have the likeliest application for the broadest number of facilities in the Minneapolis / St. Paul area. As most corridors have neither sufficient dominant peak directionality, nor the apparent ability to significantly expand the right of way envelope to accommodate widening, the project team examined managed lane strategies which incorporated use of shoulders and asynchronous deployment. Conversely, this investigation discounted a variety of options, including reversible flow, contra-flow, and dual-dual facilities.

One of the principal objectives of the MHSIS was to identify how new managed capacity could be provided with higher value and less cost. To meet this objective, the MHSIS considered the deployment of managed lanes in the context of dedicated and dynamic shoulder use. As such, the use of shoulders deserves some attention here.

As successfully demonstrated on the I-35W corridor, new managed lanes can be safely implemented with an alternative design to established managed lanes. Since the 1950 publication of the Highway Capacity Manual and 1973 AASHTO Red Book, 10 ft shoulders have been the Interstate minimum design standard for urban freeways, with 12 ft shoulders desirable on routes with heavy truck traffic. Furthermore, a minimum of 4.5 ft lateral clearance is required, with 6 – 8 ft recommended in the vicinity of pier structures. However, by the 1980s in response to rising levels of congestion and a lack of right-of-way for contemporary expansion of capacity, many states adopted the use of dedicated shoulder lanes sometimes in conjunction with or instead of narrowed lane widths. By the 1990s, only four states had chosen to extensively use shoulders and/or narrow lanes on freeways: California (Los Angeles and Bay Area), Texas (Houston), Virginia (Fairfax County), and Washington (Seattle).

In dedicated shoulder lane operations, either general purpose or HOV-specific capacity has been added through the permanent conversion of shoulders. Most HOV applications use the interior or left lane for HOV operations while the exterior or right shoulder is used for general purpose traffic so as to maintain the same number of general purpose lanes as existed prior to implementation. A typical application would convert a three-lane freeway with 12 ft lanes, 10 ft exterior shoulder, and 8 ft interior shoulder to 11 ft general purpose lanes, 14 ft (including buffer striping) HOV lane, 5 ft exterior shoulder, and 2 ft interior shoulder.

In most cases, the shoulders have been converted to general purpose capacity, at least for a short distance. However, in a few applications, the implementing agency has attempted to recover use of the shoulder for refuge purposes during some portions of the day. On Massachusetts state highways 128 and 3 in the Boston area, all vehicles are permitted on shoulders in the peak periods only. Similarly, in Virginia on I-66, the shoulder carries general purpose traffic from 5:30 – 11 am (eastbound) and 2 pm – 8 pm (westbound); however, during this time, the interior general purpose lane is open to HOV traffic only. I-66 uses extensive lane use signage in order to communicate the active times of shoulder lane service.

Bus Only Shoulders (BOS) is the most common shoulder-lane application in the United States. Additionally, Minnesota has served as a continental leader in the state of the practice, both in the extent of application of BOS lanes as well as development of policies and authorizing legislation for BOS. Minnesota's network is comprehensive, having established approximately 300 miles of BOS lanes throughout the Twin Cities since 1991. Today, BOS operations exist throughout the Twin Cities network, including long segments of I-694, I-35W, I-35E, I-94, I-494, US 169, SH 36, and US 10. Of all active BOS projects, only the Seattle region's SR-520 allows for HOV-3+ use of shoulders concurrent with buses (not including dynamically assigned HOV lanes, such as Virginia's I-66).

Dynamic (temporary) shoulder lanes is a congestion management strategy used extensively in Europe and typically deployed in conjunction with complementary traffic management strategies – such as variable speed limits (speed harmonization), queue warning, and ramp metering – to address capacity bottlenecks on the freeway network. The strategy provides additional vehicle-moving capacity during times of congestion and reduced travel speeds. When travel speeds are reduced, dynamic signs over or next to the shoulder indicate that travel on the shoulder is permitted. A complete series of traffic signs indicate operations related to temporary shoulder use, including one with a supplemental speed limit indication (used when overhead gantries are not present). Temporary shoulder use is permitted only when speed harmonization is active and speed limits are reduced, thus providing an operating environment only when speeds are managed below posted levels. In addition to allowing temporary use of the right shoulder, the Dutch also deploy the use of traveling on a shoulder on the median side of the roadway, locally termed a "plus lane," a narrowed extra travel lane provided by reconstructing the existing roadway while keeping the right hard shoulder open for travel use when traffic volumes reach levels that indicate congestion is growing.

Active Traffic Management

Although ATM may be successfully implemented in an arterial corridor, ATM in this study provides for operating conditions that enable complete use of a freeway corridor's pavement, an important component of the MHSIS. ATM does this by dynamically managing traffic flow and lane assignment based on prevailing traffic conditions and presence of collisions or other incidents. ATM has been defined by Mn/DOT as including ITS strategies which may be implemented on non-freeway arterials, including strategies such as signal coordination, cameras for incident and traffic management, and changeable messaging signs. However, for the purpose of this analysis, ATM has been confined to freeway systems with the specific components identified below.

Focusing on trip reliability, its goal is to maximize the effectiveness and efficiency of the facility under recurring congestion and non-recurring incidents or road work. Through the flexible use of the roadway, it aims to increase system performance as well as traveler throughput and safety through the use of strategies that actively regulate the flow of traffic on a facility to match current operating conditions. ATM strategies can be automated, combined, and integrated to fully optimize the existing infrastructure and provide measurable benefits to the transportation network and the motoring public.

ATM enables the use of shoulders for traffic through the dynamic assignment of lane availability. Under normal operating conditions, lane control signals inform travelers of the availability of the shoulder lane, and, eligibility for its use. In times of lane blockage or other event requiring a closure of the shoulder lane, the ATM system warns travelers upstream to merge out of the blocked lane. Coupled with other ATM efforts including speed harmonization, this merging is done at a safe speed. The combined purpose of the lane controls is to allow emergency response personnel to quickly clear the primary incident while minimizing the conditions that facilitate secondary collisions. Together, this mitigates the loss of shoulders during incidents.

ATM consists of a combination of operational strategies that, when implemented in concert with dynamic shoulder lanes, more fully optimize use of the existing infrastructure and provide measurable benefits to the transportation network and the motoring public. These strategies include but are not limited to speed harmonization, junction control, and dynamic signing and rerouting:

- Speed Harmonization / Queue Warning. Speed harmonization (also known as Variable Speed Limits) helps manage traffic by varying posted speed limits on a roadway or over each lane on an advisory or regulatory basis in real time. The deployment of the speed harmonization is automatic and begins immediately upstream of the congestion point; it does not require remote operator intervention. The system incrementally decreases speeds upstream in a cascading manner often in increments of 5 to 10 mph to smooth the deceleration of the traffic and help ensure more uniform flow while avoiding crashes.

- Junction Control. A variation of dynamic shoulder lanes involves dynamic lane assignment. Typically, the concept is applied at entrance ramps or merge-points where the number of downstream lanes is fewer than upstream lanes. This may be useful in select areas on the metropolitan network. The typical U.S. application to this geometric condition would be a lane drop for one of the outside lanes or a forced merge of two lanes, both of which are static treatments. The dynamic solution is to install lane control signals over both upstream approaches before the merge, and provide downstream lane priority to the higher volume and dynamically post a lane drop to the lesser volume roadway or approach. This is particularly effective when implemented with dynamic shoulder use at on-ramp locations where bottlenecks frequently form.
- Dynamic Rerouting. The practice involves utilizing dynamic overhead message signs or other changeable roadway signs and route markers that dynamically change the primary routing of a major thoroughfare to an alternate route where capacity is available, in response to changing with traffic conditions. If an incident occurs downstream, operators at the Traffic Management Center deploy alternate guide sign information combinations that provide alternate route information to roadway users. Similar information is also provided on full-matrix DMS installed on other roadways.

Study Process

In preparing and conducting the MHSIS, the project team first assembled information on peer communities, to determine how other metropolitan areas are evaluating the efficacy of management and operations strategies in the context of their long range plans. The findings from this assessment are provided in Section 2 (State of the Practice), and were used to inform the development of the MHSIS analysis. From this exercise, the project team prepared the performance measures for the MHSIS modeling activities. After much iteration with the Metropolitan Council / Mn/DOT project management team, the final performance measures are provided in Section 3 (Performance Measures).

Findings from the evaluation of specific projects in the MHSIS are provided in Section 4 (MHSIS Project Evaluation). This section contains detailed findings for each project identified in the MHSIS draft plan. Additionally, econometric analyses were conducted for managed lane projects as well as for active traffic management implementation. As ATM will likely be a necessary complementary strategy to managed lanes in order to mitigate concerns when using shoulder lanes, this analysis is conducted concurrent to the capacity analysis. Finally, phasing and other conclusions for incorporation within the 2030 TPP is provided in Section 5 (Prioritization Analysis).

2.0 STATE OF THE PRACTICE

Metropolitan Planning Organization (MPO) and transit agency staff from seven urban areas around the U.S. (Atlanta, Dallas-Ft. Worth, Honolulu, Houston, Miami-South Florida, San Francisco-Oakland Bay Area, and Seattle) were contacted to obtain information on how they are addressing future investments in their major highway systems, including corridor identification, application of new technology, performance measures, and funding for implementation. The detailed literature review and description of findings from this effort are provided in the Appendices. As the focus of this study is upon managed lanes and ATM analysis, this summary pertains to these topics; however, the detailed memorandum in Appendix F provides substantial findings on management strategies beyond managed lanes and ATM.

The principal finding from this effort indicates that the Minneapolis – St. Paul metropolitan area is not alone in recognizing there are insufficient funds to undertake major capacity improvement projects to meet anticipated travel demand. The Twin Cities has identified a preference for incorporating operations and management strategies into its long range transportation plan. Operations and management strategies are actively pursued to one extent or another by many peer communities. Of particular interest in the Twin Cities region are those applications that provide a long-term return on investment, so as to provide a credible alternative to unaffordable capacity expansion. These strategies would be expected to enhance traffic operations through flow maximization, improve person throughput through increases in average vehicle occupancies and transit ridership, reduce incidents and crashes, and improve travel time reliability. In the United States, common types of managed lanes are HOV lanes, HOT lanes, Express Toll Lanes, and limited-access express lanes. Active traffic management as deployed in Europe attempts to regulate the flow of all vehicles across all lanes of traffic through the implementation of speed harmonization, queue warning, lane controls, junction controls, dynamic rerouting, and dynamic travel time information.

The nature of managed lanes in certain communities has evolved from a short-term, corridor-specific, operationally-focused strategy to a long-term, system-wide, mobility-focused strategy. Although project development still occurs at a corridor level for managed lanes, capacity planning and systems integration are increasingly conducted at a regional / system level. In this context, managed lanes are often considered side-by-side with active traffic management.

There is no established guidance for the incorporation of management and operational strategies within the context of the long-range plan. Indeed, the development of the long-range plan as a 20- or 30-year snapshot of the future network is inherently biased towards identifying capacity improvements.

Although many communities have attempted to incorporate managed lanes within the long range plan, these projects are often simply identified as an alternative line on a map compared to a capacity expansion. The one exception to this practice is the San Francisco Bay Area, which has fundamentally changed the development of the long range plan through the Freeway Performance Initiative (FPI). The FPI created a system-wide evaluation of regional project priorities, but developed the list of priorities in partnership with the project sponsors. Thus, when projects were proposed for development or inclusion with the long range plan, the phasing of the project in the FPI determined its suitability for inclusion. If iterative steps (as identified in the FPI) were not conducted first, the project was not included. This prevents big-capacity projects from absorbing regional funds. Furthermore, it shows a preference for operational and management treatments that maximize the use of available capacity before new capacity is added to the system.

A common element amongst all peer communities is an active avoidance of "big infrastructure" projects from absorbing identified and anticipated regional funding. Big infrastructure projects include bridges, tunnels, and interchanges that exist within a constrained environment, making substantive improvements and/or capacity enhancement cost prohibitive. In such cases, many urban areas (such as the Seattle, Dallas-Fort Worth, and San Francisco-Oakland regions) have established a policy preference for evaluating and implementing user-based financing as a means of paying-down the cost of these facilities. In most cases, these big infrastructure projects involve tolls across all lanes of traffic into perpetuity, providing a base of funding for the large capital outlay and for lifecycle considerations for operations and maintenance. In all cases, the intent is to separate the obligations for building these structures from available highway trust fund revenue.

Outside of big projects, tolls remain an important force for infrastructure development. In Texas, the legislature provided a range of new transportation financing options for regional MPOs to consider in funding needed infrastructure. These tools include loans from the state infrastructure bank, local community-financed shadow-tolling, traditional toll financing, and public-private partnerships allowing for private activity bond financing and comprehensive development agreements. Other states have also enabled greater use of private-sector and toll financing for infrastructure. Unlike the big infrastructure projects, in most applications, tolls are to be applied for new lanes of traffic only or on converted HOV / shoulders.

In the project development process, toll viability screening has been successfully used to ensure revenue production possibilities are examined to complement public revenue. For example, the Dallas-Fort Worth region evaluates all new highway capacity using federal aid funds for toll road viability. Since adoption in 1993, the region expanded the policy to include express toll lanes and managed lanes. As a result, the region has an extensive projected network of toll and managed lanes facilities, with little new "traditional highway" capacity due to be constructed, unless it is concurrent with new toll lane capacity (such as improvements to frontage roads).

An interesting development witnessed in various metropolitan areas is the extensive use of regional partnerships to implement operational and management strategies for congested freeway corridors, and, to deliver new managed lane capacity projects. Although financing is a key consideration within the development, it should be noted that this extends beyond financial considerations. Partnerships with regional / county authorities, as well as non-profits (transportation management associations) and private-sector enterprises, have helped bring projects to fruition quicker and with greater regional concurrence.

3.0 PERFORMANCE MEASURES

The performance measures considered in the evaluation of the MHSIS alternatives were based on the recommendation of the Mn/DOT Metro District and the Metropolitan Council to provide "a lower-cost/high-benefit approach [that] may be an effective way to address specific problems and that pricing can provide an alternative for managing congestion." This recommendation was developed from the transportation investment policy framework of the 2030 TPP, adopted in 2009. Furthermore, during outreach efforts associated with the TPP and MHSIS, members of the public provided their opinions on how the performance measures should be prioritized.

The MHSIS performance measures were derived from the policy direction of the 2030 TPP, adopted in 2009. This derivation provides evaluation guidance for corridor-based alternatives, including the designation, design, and components of managed lane strategies upon the highway system. To measure the impact of the managed lane strategies, it is essential to make comparisons between managed lane alternatives and to a baseline – often know as a "build" and "no-build" concept comparison. This comparison lends itself to quantifiable measures of effectiveness that allow for comparability.

Ideally, a comprehensive managed lane performance analysis would examine the contribution of managed lanes to differing operational conditions, land uses within treatment corridors, and recurring / non-recurring traffic congestion situations. However, the performance measures used in the MHSIS are limited by the capabilities of the modeling. Furthermore, the performance measures utilized for the MHSIS focus upon traditional system measures, as the benefits to the system (reflected in aggregate metrics) are more directly relevant to the MHSIS policy direction for "lower-cost / higher-benefit" approaches to congestion relief. Conversely, individual benefits from managed lanes (such as individual travel time savings and reliability) are inherently understood by users, but may not reflect the regional choice for a managed lanes strategy.

Based on this approach, the MHSIS has focused on the following performance categories to guide the future investments in the Metropolitan Highway System.

INCREASE THE PEOPLE-MOVING CAPACITY OF THE METROPOLITAN HIGHWAY SYSTEM

Person throughput is an important measure of mobility and congestion reduction. Person throughput refers to the number of persons traversing the corridor on both transit and in private vehicles. Increases in the number of persons using a corridor would imply that the operations and management strategies evaluated were effective in serving more persons who are not serviced in the corridor because of the congestion that is present in a no-build context. The identified measures of effectiveness for person throughput are:

- Daily new vehicular trips per lane mile
- Daily new person trips per lane mile

MANAGE AND OPTIMIZE, TO THE GREATEST EXTENT POSSIBLE, THE EXISTING SYSTEM

Travel time is strongly influenced by the speed that the vehicle is able to travel, as well as any delays experienced due to bottlenecks or other queues caused by congestion. Generally, travel times are measured for specific points on a section of roadway and can be collected separately for different types of facilities (e.g., general purpose lanes versus managed lanes, freeway versus arterial). The MHSIS evaluated the travel time savings by examining changes in travel times before (no-build) and after (treatment) the strategies have been applied to treatment corridors. The temporal extent of congestion refers to how many hours in the day the corridor is operating under congested conditions. As freeway corridors have varying levels of operations and management strategies deployed across treatment sections, this will affect the percentage of VMT experiencing congestion on the metropolitan system. The intent of the evaluation will be to identify the level of success the strategies have upon treatment corridors to this objective.

The identified measures of effectiveness for optimization are:

- Daily reduction in Congested VMT
- Daily reduction in Peak Hours of Delay per Trip
- Daily reduction in Average Travel Time per Trip

REDUCE FUTURE DEMAND ON THE HIGHWAY SYSTEM

A desired outcome of the MHSIS is to increase the use of transit relative to the private auto, leading to a mode shift to transit. Mode shift may result from potential users being attracted to transit, or from increased transit use among occasional users. Thus, the central transit evaluation issue is the identification and measurement of mode shift. In theory, a mode shift to transit should then facilitate higher transit ridership, reduced levels of traffic congestion, more efficient use of existing road capacity, net reduction in greenhouse gas emissions and fuel consumption, improved freight movements, and potentially higher levels of person throughput.

The identified measures of effectiveness for demand reduction are:

- Change in transit mode share
- Change in corridor attractiveness for SOV trips

IMPLEMENT STRATEGIC AND AFFORDABLE INVESTMENTS

Given the need for a lower-cost/high-benefit approach for the MHSIS, cost effectiveness is an important consideration. The most important element to maximize the potential of cost effectiveness is having a strong working knowledge of the phasing of many of these corridors. If there are plans to develop a certain segment of a corridor from another office or agency, there should be understanding of how that project will fit in with the long term vision of the MHSIS. This could be something as major as a bridge reconstruction or something as minor as a mill and overlay that could save millions in future investment in the corridor. The MHSIS endeavored to incorporate a qualitative investment opportunity rating to reflect these opportunities for consolidation of expenditure.

Another way of optimizing cost effectiveness is to identify an appropriate staging between ATM and managed lane projects. For managed lanes in constrained conditions and/or where it is anticipated utilizing the shoulder, then those projects may be phased in conjunction with appropriate ATM strategies. Furthermore, this could be done concurrently with strategic capacity projects in other areas of the region, thereby spreading around projects that provide immediate benefit.

- Cost effectiveness, calculated as a benefit / cost valuation
- Standard deviation in cost effectiveness
- Investment opportunity rating
- Investment parity rating

Public Comments on Performance Measures

The MetCouncil and Mn/DOT conducted selected public outreach efforts concerning the MHSIS in April 2010. During those meetings, participants were asked to rank their preferred prioritization for performance measures to be used in the MHSIS. The findings, shown in Table 3, indicate overall preference for enhancing person throughput and providing travel time savings. These measures have been incorporated in the performance analysis that follows.

TABLE 3: PUBLIC OUTREACH FINDINGS FOR PRIORITIZATION OF PERFORMANCE MEASURES

Objective	Performance Measure	Transport Alliance	Hennepin County	Carver County	Anoka County	Total
Increase people-moving capacity of metropolitan highway system	Person throughput	21 50.0%	12 30.0%	10 35.7%	9 20.5%	52 35.9%
Provide alternatives to traveling in congested conditions	Travel time savings	5 11.9%	4 10.0%	10 35.7%	16 36.4%	35 24.1%
Implement strategic and affordable investments to manage use of existing facilities	Cost effectiveness	8 19.0%	5 12.5%	4 14.3%	6 13.6%	23 15.9%
Increase trip reliability for corridor users	Reductions in trip delay	6 14.3%	2 5.0%	1 3.6%	1 2.3%	10 6.9%
Encourage increased transit use	Transit suitability assessment	2 4.8%	8 20.0%	3 10.7%	12 27.3%	25 17.2%

4.0 MHSIS Project Evaluation

Initial Project Concepts

Initially, a total of 41 separate projects were identified for analysis in the MHSIS. Thirty-four of these projects were developed by the MHSIS Project Management Team (PMT), comprised of Mn/DOT and MetCouncil representatives, prior to the conduct of the MHSIS study. Seven additional facilities were added to the MHSIS analysis based upon preliminary study corridors identified by the MnPass System Study Phase 2. These projects included managed lane expansion projects (building a new concurrent flow managed lane), managed lane conversion projects (adapting an existing general purpose lane into managed lane operations), interchange closure, multiple interchange consolidation, limited access design conversion, strategic capacity expansion, and expressway expansion. However, as the MHSIS PMT focused the MHSIS analysis upon managed lanes, the other strategy elements were placed within the purview of other efforts – including the Congestion Mitigation and Safety Program (CMSP), 2030 TPP Update, and related planning. Finally, during the course of the MHSIS, Mn/DOT conducted an update to the MnPass System Study, which adopted a policy of managed lane expansion only. Given the desire for concurrence and performance metrics which indicated a preference for expansion over conversion, only managed lane expansions were forwarded for analysis in this Final Report (full analysis of the conversion projects may be found in the technical appendices).

TABLE 4: MHSIS PROJECT LIST

Corridor	Label	From	To	Type of Project
I-35E	35E-1	Maryland	TH-36	Managed Lane Expansion
I-35E	35E-2	TH-36	County Rd E	Managed Lane Conversion
I-35E	35E-3	CR E	CSAH 14	Managed Lane Expansion
I-35W	35W-1	42nd St.	Minneapolis CBD	Asynchronous Managed Lane
I-35W	35W-2	University Ave	TH-280	Managed Lane Expansion
I-35W	35W-3	TH-280	95th Ave. N.	Managed Lane Expansion
I-394	394	I-494	I-94	Managed Lane Expansion
I-494	494-1	TH-55	I-94 / I-494	Managed Lane Expansion
I-494	494-2	TH-169	TH5	Managed Lane Expansion
I-694	694-1	I-35W	I-35E	Managed Lane Expansion
I-694	694-2	I-94	I-35E	Managed Lane Expansion
I-94	94-1	TH-101	I-94 / I-494	Managed Lane Expansion
I-94	94-2	Cedar	Marion	Managed Lane Expansion
I-94	94-3	St. Paul	I-694	Managed Lane Expansion
TH-280	280	I-94	I-35W	Managed Lane Expansion
TH-36	36-1	I-35W	I-35E	Managed Lane Expansion
TH-36	36-2	I-35E	I-694	Managed Lane Expansion
TH-77	77	CSAH 42	I-494	Managed Lane Expansion
US-169	169-1	I-394	I-694	Managed Lane Expansion
US-169	169-2	TH-62	I-394	Managed Lane Expansion
US-169	169-3	Minnesota River	TH-62	Managed Lane Expansion

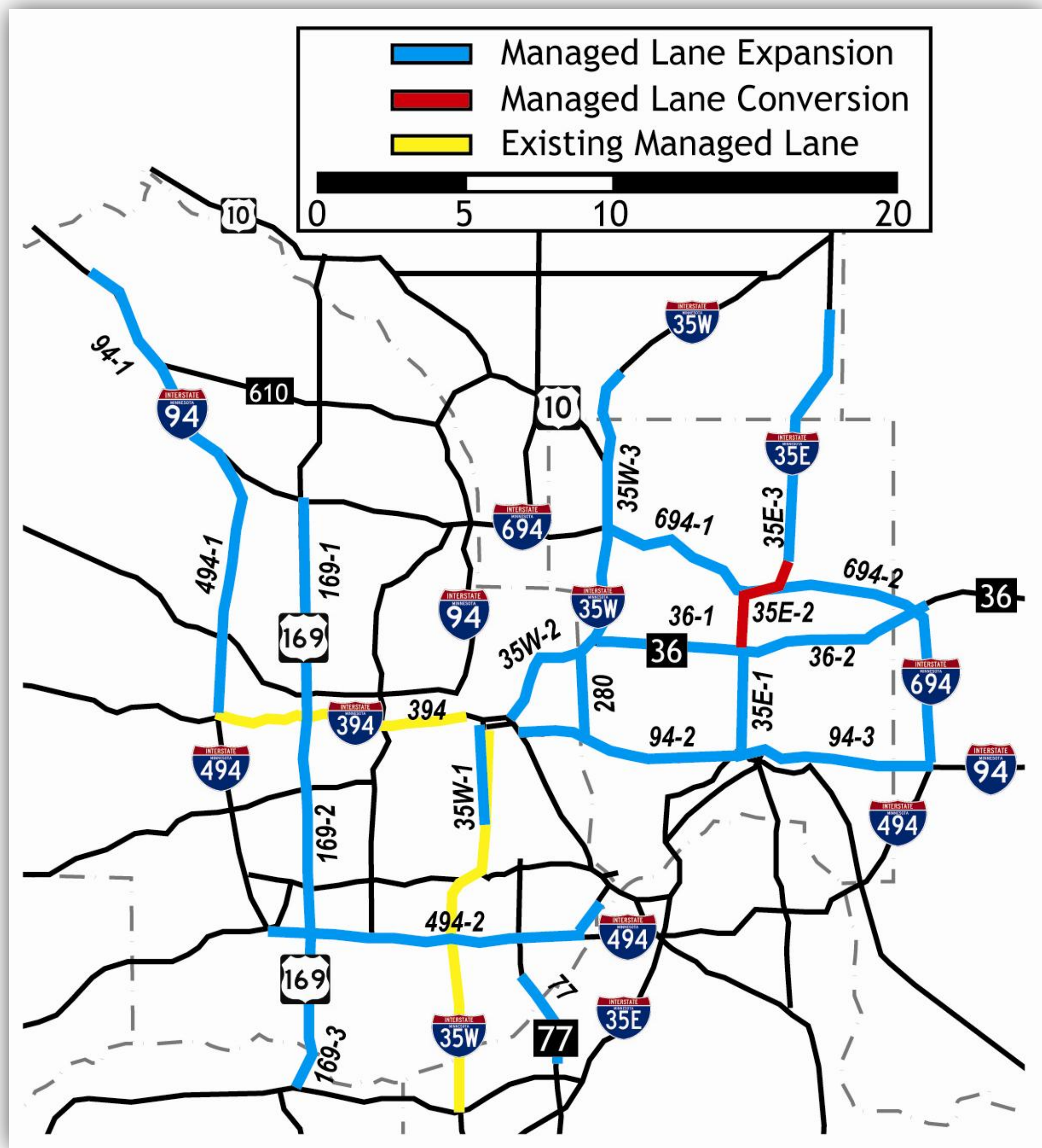


FIGURE 6: MHSIS MANAGED LANE UNIVERSE OF PROJECTS (MAP)

Conceptual Applications in the MHSIS

The MHSIS combines a number of management and operations strategies in order to achieve the vision of a lower-cost, higher-value highway improvement program. Early in the project and continuing through subsequent analyses, the project team developed the concepts and associated cost estimates for active traffic management and managed lanes strategies for the metropolitan highway network. Input for identification of conceptual design came from a review of established concepts developed by Mn/DOT and the Metropolitan Council, available and collected traffic and related data, corridor field visits, and input from project management team and steering committees.

Managed Lane Design Components

The following comprise the current design standards as established by the AASHTO *Guide for High Occupancy Vehicle (HOV) Facilities, 3rd Edition (2004).* These standards represent established preferred design components for contiguous single-lane managed lane facilities, added in freeway corridors without HOV lanes. Currently, deviations from these standards require a design exception from the Federal Highway Administration (FHWA).

- *Widths:* 12-ft lane widths, with a 2-ft buffer; 10-ft residual shoulders on one or both sides of the mainline roadway
- *Access:* Where access is restricted for left side lane orientations, minimum weaves per lane are 600 ft per main lane weave upstream and downstream of respective ingress and egress zones. For entrance ramp to the managed lane, from the nearest upstream right side ramp where ramp taper joins the main lanes to the beginning of the solid stripe leading into the lane. For exit ramp from the managed lane, the distance from where the managed lane exit ramp stripe tapers to join the left mainline edge stripe to the right side gore of the next downstream right side exit from the main lanes.
- *Design Speed*: Same as freeway or ramp (35-65 mph)
- *Grade (maximum):* 3% for mainline, 6% for ramps
- *Design vehicles*: All classes except trucks of more than three axles

Concurrent-flow managed lanes were the preferred approach to identified concepts for the metropolitan highway system. Contraflow, reversible and barrier-separated treatments were not considered as discrete options in the MHSIS, due to operational and design challenges with these implementations (except for ramp connections to/from Downtown Minneapolis, downtown St. Paul, and the existing I-394 MnPass lanes). As the regional managed lane system moves from conceptual planning, in this document, to preliminary engineering and interim design, these design options may be considered in appropriate corridors. For consistency, concurrent flow treatments, focused primarily on the inside shoulders, were assumed for all managed lane implementations.

Some form of delineation is needed for any kind of concurrent-flow lane to differentiate it from adjacent lanes, at least during the operating periods. AASHTO's latest guidance recommends buffers for concurrent-flow lanes, consistent with existing Mn/DOT implementation on I-394. Figure 7 shows typical sections for desirable and minimum conditions. A variety of design techniques exist for buffer separated lanes. The buffer width should nominally be 2 to 4 feet and no less than 1.5 feet. A much wider buffer width of 6 to 8 feet may appear as a refuge for vehicle breakdowns where high speed traffic exposes the driver to a safety hazard on both sides. It is difficult to accommodate the requisite pavement markings in a buffer of less than 18 inches. A buffer separated lane may apply a conventional 4-foot buffer and reduce the buffer area around such isolated restrictions as bridge columns for short distances. Ideally such conditions are appropriately facilitated by varying the inside shoulder width to keep the lane alignment straight through the impediment. If continuous access is allowed, a single wide or double skip stripe placed around and within the buffer area is appropriate. If access is restricted, single or dual solid stripes are applied and broken wherever access is permitted.

Although the current guidance provides for buffer separation as noted, the implementation of MnPass lanes on I-35W south of TH-62 provide for 70 percent continuous access striping, without any differential separation between the managed lanes and the leftmost general purpose lane. This striping is a notable departure from practice around the U.S. and is the subject of evaluation by Mn/DOT and the FHWA. If this evaluation indicates positive findings from continuous access striping, the buffer requirements may be further reduced from the established guidelines. This will be an important consideration in preliminary engineering and/or interim design activities for MHSIS recommended facilities.

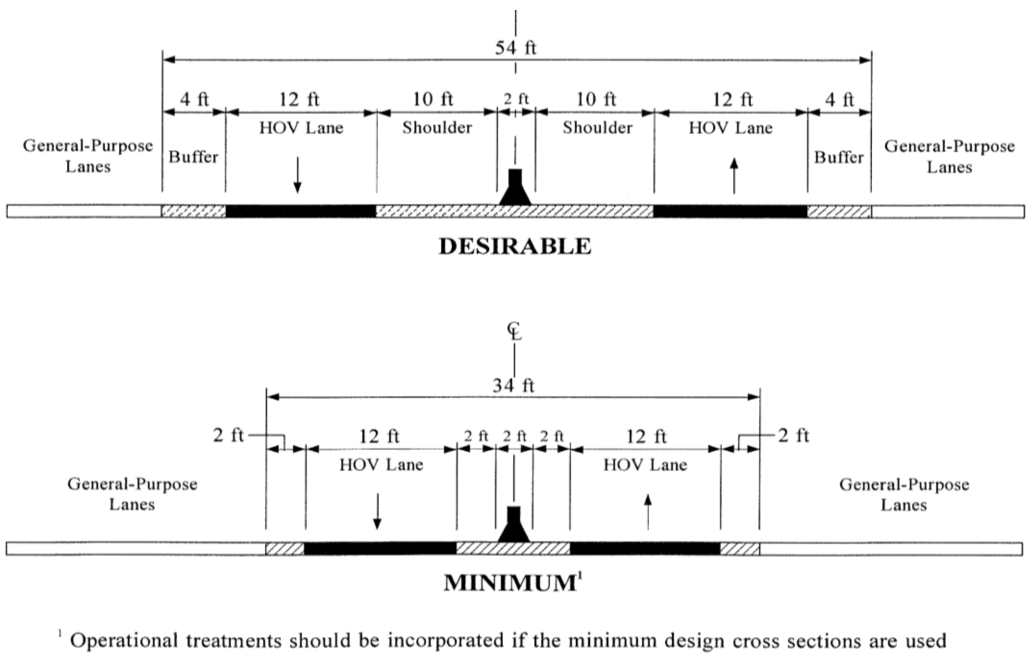


FIGURE 7: CONCURRENT FLOW BUFFER SEPARATED CROSS SECTIONS

Most MHSIS candidate settings for concurrent flow managed lanes have right-of-way, bridges and related impediments that make widening to full design standards extremely difficult or cost prohibitive. As such, careful study of the proper trade-offs for lane, shoulder and buffer widths are warranted. These conditions are herein referred to as minimal designs, which often involve the removal or reduction in existing inside breakdown shoulders and perhaps slight reductions in some lane widths for the added lane. While trade-offs in each case will vary depending on site conditions, Table 5 provides a reference of commonly applied priorities when trying to accommodate key design features in constrained settings.

TABLE 5: SUGGESTED SEQUENCE OF CONCEPTUAL TRADE-OFFS FOR CONCURRENT-FLOW LANES

Sequence	Cross Section Design Change
First	Reduce managed lane left lateral clearance to no less than 2 feet.
Second	Reduce freeway right lateral clearance (shoulder) from 10 feet to no less than 8 feet.
Third	Reduce buffer separation between the managed and general purpose lane to no less than 1.5 feet.
Fourth	Reduce managed lane width to no less than 11 ft. (Some agencies prefer reversing the fourth and fifth trade-offs when buses or trucks are projected to use the managed lane. The buffer markings may encroach on the 11-foot width.).
Fifth	Reduce selected mixed-flow lane widths to no less than 11 feet. (Leave at least one 12-foot outside lane for trucks).
Sixth	Transition barrier shape at columns to vertical face, or remove buffer separation between the managed lane and general purpose lanes.

Whereas the above trade-offs represent existing guidelines for facility design, the future network envisioned in the MHSIS suggests an aggressive deployment of ATM to complement the implementation of managed lanes for capacity expansion. Based upon established practice in Europe, ATM is useful as a safety and operational mitigation device in the use of shoulder lanes. The managed lane concepts under consideration in the MHSIS were determined to benefit from selective application of available ATM strategies, notably connector and ramp metering, lane control signals, queue warning, and speed harmonization. Ramp metering is already prevalent throughout the network and provides benefits in smoothing critical merge activity and in delaying the onset of congestion. However, if the new managed lanes were to use shoulders, any sudden and unexpected formation of queues can contribute to unstable flow, loss of throughput and higher incidence of crashes. These treatment segments in the respective peak periods would appear to be appropriate for the implementation of speed harmonization and queue warning to compliment ramp and connector metering and the shoulder lane control options being considered for managed lanes.

Much like the I-35W Priced Dynamic Shoulder Lane (PDSL) project, speed harmonization and queue warning increase efficiency and improve operational safety. Together, such systems provide a means of advising an approaching traffic slow-down and slowing traffic down gradually so that crashes and secondary incidents are avoided. Desirable placement of gantries for mounting the speed harmonization and queue warning signing would be approximately every ¼ to ½ mile such that one is always in sight. If desired, use of the large number of overhead bridge structures to support the added signs could minimize the potential cost associated with installation of this strategy, although free-standing gantries are currently preferred by Mn/DOT.

As applied on I-35W, the right side shoulder is permanently converted to a general-purpose lane, with ramps realigned to meet the shoulder treatment. The inside shoulder is expanded to 14 feet, with use allowed for eligible traffic during peak periods, reverting to breakdown / refuge only in off-peak periods. ATM is used to manage flows, and provide warnings of downstream incidents. Additionally, emergency refuge areas are constructed every ¼ mile whenever an interchange is not available downstream.

In order to meet the policy of objective of the MHSIS, the reduced shoulder option is the evaluated design concept for managed lane facilities in the MHSIS. As shown in Figure 8, the existing pavement width is maintained with the conversion of the shoulder to managed lane operations. As appropriate, the managed lane may be closed in the off-peak periods, as is currently conducted on I-35W. This is a noted departure from the existing AASHTO standards (2004) and would require a review and design exception from the FHWA prior to implementation. That said, many of the managed lanes may be constructed within standards and meeting the MHSIS policy objective, as concluded by the MnPass System Study Phase 2. Individual corridor and segment design will be dependent upon the completion of a preliminary engineering and interim design process, with full participation of all affected parties. However, for the purpose of this planning study, the reduced shoulder option was applied consistently across all corridors and segments.

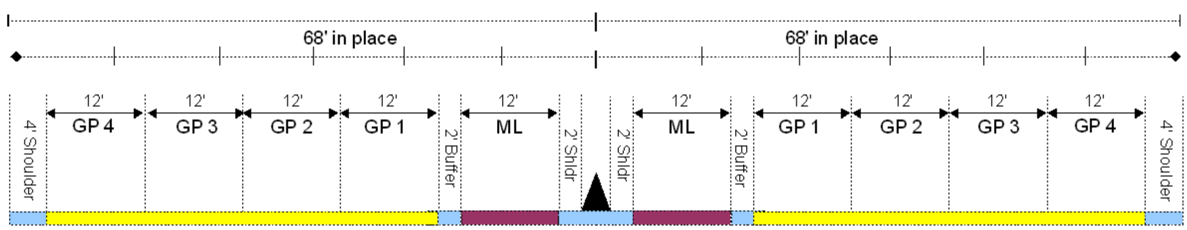


FIGURE 8: MHSIS TYPICAL CROSS SECTION FOR REDUCED SHOULDER MANAGED LANES (BI-DIRECTIONAL)

COST ESTIMATION

The cost estimation used in the evaluation of the MHSIS alternatives are based on the recommendation of the Mn/DOT Metro District and the Metropolitan Council to provide “a lower-cost/high-benefit approach may be an effective way to address specific problems and that pricing can provide an alternative to manage congestion and for managing congestion.”

METHODOLOGY

The application used for providing lower-cost/higher-benefit was to maximize the amount of proposed roadway that could be used on the existing footprint of the highway system. This creates areas where the proposed roadway may need to squeeze under an existing bridge structure (such as the existing northbound I-35W to westbound I-494 ramp under I-494) or have areas that may need design exemptions to be approved prior to construction. In the event that a roadway width will need to increase, the less right-of-way that would need to be acquired would go a long way towards finding a lower-cost/high-benefit solution. Right of way costs may also need to be consider noise abatement, ponding, drainage, and other mitigation activities, which are not incorporated as line item in the MHSIS (rather, areas with anticipated issues carry a higher risk factor).

Providing a full pavement reconstruction may also greatly increase the cost of a corridor that is in need of congestion management. One other way to provide a lower-cost/higher-benefit approach to the project is to consider using a mill and overlay on the existing roadway surface and creating a full pavement structure on the areas that are either existing shoulders that are below standards for a general purpose lane or grass areas that are currently adjacent to the existing roadway that would need a pavement section for the shoulders or drive lanes. Ideally, such projects would occur at the time a pavement preservation and/or a bridge(s) replacement project is due to take place, in order to create cost effective synergies in activities.

The costs for each corridor studied in the MHSIS are for construction cost only. Although operations and maintenance (O&M) costs are significant for managed lanes and ATM infrastructure, these costs are currently offset (by policy and practice) with toll revenue. As revenue generation was not a component of the MHSIS analysis, O&M costs are likewise excluded. Delivery cost will be excluded due to many unknown funding conditions and to maintain consistency between alternatives. The cost estimates also include a low and high range. The range is used to help clarify complexities within certain corridors that may have more factors associated with those corridors than a standard add lane/mill and overlay project. The most significant line item for these factors is bridge structures. Finally, some facilities have specific estimates developed by either 1) previous or current Mn/DOT analyses, or, 2) the MnPass System Study Phase 2 effort. In order to provide consistency in comparisons, the MHSIS methodology for cost estimation was used on all corridors; if these cost estimates from other efforts are known, they are noted in the project documentation. In many cases, these specific estimates may change the cost effectiveness analysis.

The line items used for the cost estimation are divided into the following categories:

- Pavement Construction (New pavement and mill and overlay of existing pavement)
- Managed Lane ATM Infrastructure
- Grading and Drainage
- Miscellaneous (Sign Bridge Relocation, Median Barriers, etc.)
- Bridge Structures
- Risk Factors

The line items that were not included within the MHSIS study are listed below:

- Right-of-Way Property Acquisition
- Upgrade to the Lighting System
- Proposed Retaining Wall Structures

Detailed corridor-by-corridor cost estimates are provided in the appendices.

The ATM infrastructure cost estimate recognizes the information that was provided by Mn/DOT for the I-35W corridor located south of downtown Minneapolis. The cost estimates used for the managed lane corridors using ATMs assume a half mile gantry spacing similar to I-35W. These numbers also assume an upgrade to the existing fiber and power mainlines that run in parallel with the roadway. There has also been some allowance for the adjustment of existing infrastructure including Closed Circuit Television (CCTV) cameras and adding dynamic messaging signs. Due to the sign bridge widths needing to expand wider than the proposed roadway, the costs will vary based on the width of the roadway.

A standard unit of cost was applied to each corridor on a per mile basis. This number was not changed between the low and high range; however in areas that may have more drainage concerns, a higher risk factor has been applied to the corridor. Unlike the low range, the higher range took into account a potential need for noise walls, as well as more cost allocated to sign bridges or more median barriers.

The corridors that had bridges that are in need of widening were given a range based on if the overpass could add the new infrastructure on to either side of the roadway or if a new bridge replacement and signal upgrade was warranted. If a bridge was in need of an overpass replacement or the widening required a bridge replacement, a lump sum $5 million was applied to these conditions for the higher range. In most cases the goal of providing lower-cost/higher benefit solutions was used to try to fit the new roadway infrastructure within the existing bridge footprint wherever possible.

Since the cost of acquiring right-of-way is not included in the estimates, a higher risk factor was applied to areas within the I-694/I-494 ring. These areas should place a higher priority of fitting as much proposed roadway into the existing pavement footprint given the value of the adjacent land. Also included in the higher risk category were areas with known drainage concerns that would not have been captured in the standard drainage line item. Corridors with many bridge structures that have some areas of concern, but would require design exemptions were also given a higher risk factor. The higher risk corridors used a risk of 25% for the low range and 35% for the higher range. The risks used for areas with less variance and right-of-way concerns were given a risk of 15% for the low range and 25% for the higher range.

Comparison to MnPass System Study Phase 2

The MHSIS Study was completed concurrently with the MnPass System Study Phase 2. Although these studies were conducted with different objectives and timeframes for analysis, the measurements used for cost were mirrored closely between the two studies; however there are four primary areas where the MHSIS study differed from the MnPass Study. First, the MHSIS did not include any cost for direct connections between managed lane facilities; however, the MnPass System Study Phase 2 did look into the geometrics and cost for how a managed left lane structure would connect into the downtown exits. As the presence of direct connection was not included in the performance modeling, these costs are excluded from the MHSIS. However, the benefit of the connections has been evaluated as a part of the MnPass System Study Phase 2 and should be considered valid for correlation to MHSIS projects. Second, the MHSIS applied a lower miscellaneous cost for the corridors, but was balanced out by the risk factors. The MnPass System

Study Phase 2 applied the same risk factor to the low and high range. In contrast, the MHSIS used risks that varied by 10% between the low and high ranges. Third, the MnPass System Study Phase 2's timeframe for analysis was 2-10 years, with a keystone analysis of year 2015, whereas the MHSIS used a 20-year timeframe with the year 2030 as the keystone. Finally, the study corridors did not perfectly align between both studies. As a result, segment consideration may drive differences between the MnPass and MHSIS study corridors. These differences are reflected in Table 6 prepared by the MnPass System Study Phase 2.

TABLE 6: COST ESTIMATE DIFFERENCES BETWEEN MHSIS AND MNPASS SYSTEM 2 STUDIES

Corridor	Length (mi)	MHSIS (low)	MHSIS (high)	MnPass (low)	MnPass (high)	Reason for Discrepancy
TH 36: I-35W to I-35E	5.0	$39 M	$56 M	$35 M	$60 M	Roughly equivalent
I-94: TH 101 to I-494	9.0	72	101	70	95	Roughly equivalent
I-35E: I-94 to TH 36	3.9	35	48	75	90	Different segment limits
I-35E: TH 36 to CR E	3.8	7	12	30	40	MHSIS studied lane conversion
I-35W: DT Minneapolis to TH 36	5.3	47	60	95	115	Different segment limits
I-35W: TH 36 to Blaine	10.8	140	190	130	180	Different segment limits
I-494: TH 212 to I-394	9.0	130	167	70	125	Different segment limits
I-494: I-394 to I-94	8.5	61	61	61	61	Mn/DOT estimate
TH 169: CR 17 to I-494	10.0	93	116	80	115	Different limits and design
TH 77: 141st Street to I-494	6.9	41	41	41	41	Mn/DOT estimate
I-94: DT Minneapolis to TH 280	3.0	41	41	41	41	Mn/DOT estimate
I-94: TH 280 to DT St. Paul	5.1	62	62	62	62	Mn/DOT estimate
I-494: TH 212 to MSP Airport	10.6	130	155	150	185	Different segment limits

Opportunity-Driven Cost Reduction

One of the main recommendations of the MHSIS is for the continued communication and coordination between the agencies on implementation of the desired project concurrently with the preservation of other maintenance or design projects. Examples of these situations could vary from an existing bridge that is programmed for replacement or a standard mill and overlay preservation project to a strategic capacity enhancement that would perform even better with additional ATMs. The corridors listed below have been funded for future enhancements.

The I-35E corridor was studied in the MHSIS with the potential of performing well in the cost benefit analysis. If the Cayuga bridge project implements some of the ATM infrastructure studied in the MHSIS, the impact could be equally as high at a fraction of the cost. Also, receiving funding is the I-694 corridor between the Highway 10 / Snelling Ave / Hamline Interchanges. This corridor may have more funds added to connect the Highway 10 Project with the "unweave the weave" project at Rice St. These improvements coupled with new interchange improvements at I-35W and I-694, and the corridor will perform at a much higher level. Also programmed for improvements along the I-35W corridor are two bridges just south of downtown Minneapolis.

Performance Analysis

A total of 41 candidate projects were evaluated. While representative of the overall set of new projects being considered, these corridor alternatives should not be considered an exhaustive or exclusive list. The performance evaluation for these projects was conducted using two approaches.

To measure the benefits of capacity enhancement, the regional travel demand forecast model (the regional model) was used. Secondly, the project team used the ITS Deployment Analysis System (IDAS) to measure the benefits of ATM strategies. Detailed descriptions of both models' methodologies and findings are provided in Appendices.

The Metropolitan Council technical planning support staff coded 23 separate network scenarios for forecast years 2030 and 2060 that contained the 41 selected corridor projects. In addition, model runs were done for 2030 and 2060 for the no-build condition. Using this approach, the project team developed a database of corridor-specific performance measures on a link and origin-destination trip basis, computing the measures of effectiveness identified previously. Each of these measures could be summarized by several different categories, including facility/lane type, volume/capacity ratio, trip length and/or time of day.

The IDAS model evaluated the various ATM techniques that would best serve the needs of the Minneapolis / St. Paul region. After considering 1) a dynamic re-routing system, and 2) a speed harmonization (including queue warning) and lane control system, it was decided by Mn/DOT and the project team that the latter alternative would be the preferred ATM strategy for analysis. Six corridors, comprising most of the capacity projects under consideration, were selected for studying the deployment of the ATM system. The selection of the corridors was based on the 2005-2007 freeways and major expressway crash map and the 2008 metro freeway congestion maps for the morning and evening peak periods.

A comparative cost-benefit analysis was used to analyze the different alternatives. The analysis enabled the development of an ATM deployment strategy and helped integrate it into the managed lane vision for the region.

MHSIS Analytical Findings

The results of the evaluation efforts are described based upon the analytical tools. As the two primary tools yield incomparable results, they cannot be combined. However, as the ATM deployment is viewed as a supporting element to capacity projects envisioned in the managed lane and strategic capacity expansion considerations, it is not necessary to integrate the results. The ATM analysis is described first, as it provides a basis for understanding the benefits of ATM as a discrete system and how it can support the managed lanes system.

ATM Evaluation

The first step in the analysis process using IDAS was to run trip assignment for each of the ATM alternatives, so as to redistribute trips on the network based on the ATM elements deployed on the network. Once trip assignment was run it computed changes in vehicle miles of travel (VMT), vehicle hours of travel (VHT), average speed, number of person trips, etc. Using these measures, IDAS identifies the dollar value for the benefits of the improvement relative to the cost of implementation of the system. The benefits values were annualized and total of all these benefits values was calculated as the "Total Annual Benefits". Similarly during the analysis process the capital costs and the operations and maintenance costs for the ATM equipment deployed were computed and annualized. This was reported as the "Total Annual Cost". In order to compare between the various alternatives, IDAS provided the values for the "Net Benefits" (Total Annual Benefits – Total Annual Costs) and the benefit to cost ratio.

Looking at the benefit cost summary for both the AM peak period and the PM peak period, implementing speed harmonization / lane control system yields positive net benefits on all the identified corridors. This means that investment in deploying the ATM system on the corridors would yield benefits for the metropolitan highway system and help improve the operation of the system, as shown in Table 7. It should be noted that this list does not reflect the costs of ATM deployment already conducted in the I-94 and I-35W corridors, which would improve the relative rating.

TABLE 7: BENEFIT-COST RATIO OF ATM ALTERNATIVES

Corridor	Benefit / Cost Ratio (AM peak; PM peak)
TH-36	17.14 / 60.52
TH-62	17.03 / 62.12
I-35W	15.42 / 49.99
I-35E / I-694	15.42 / 56.87
I-494	13.42 / 45.12
I-94 / I-394	6.81 / 27.54

Overall, it can be said that the results of the analysis show that ATM deployment on the corridors would provide an effective means of managing these corridors and would make for an efficient and cost effective strategy for mitigating operational and safety concerns when utilizing shoulder lanes. As such ATM should be an integral part of the long range transportation plan for the region.

Managed Lane Project Findings

The managed lane projects were examined using the travel demand forecast model as described in the methodology. As noted previously, the measurement of these findings is on a *system* scale. As a result, the benefits accrue to all participants in the managed lane's commuter shed. Thus, if the project affects trips not only using the managed lane corridor (both users and non-users) but also those of parallel facilities, the findings translate to aggregate benefits across the entire commuter shed. At times, this may yield contradictory or confusing results based upon what would be anticipated for a *commuter using the managed lane*. It is worth reiterating that the benefits shown here do not reflect that commuter, but rather, the aggregate experience across *all travelers* in the commuter shed for that managed lane improvement.

THROUGHPUT

As the travel demand model held regional vehicular trip-making static, the measures of effectiveness for person and vehicular throughput in the model results only reflect how much the project expands the market it is serving. An expansion of one market by the project yields a contraction of another market (e.g., I-494 drawing more vehicles from US 169, not necessarily serving more people in aggregate). So, this measure provides a perspective on the size of the market affected by the project. When calculated as person / vehicle throughput per directional lane mile, the effect is to evaluate how many travelers are potentially served by the project. The greater the service per mile, the greater the spatial scope of effectiveness. The results of the throughput analysis are seen in Table 8 and Figure 9.

TABLE 8: MANAGED LANE PERFORMANCE ASSESSMENT: THROUGHPUT

Corridor	From	To	Net Vehicles per Lane Mile	Net Persons per Lane Mile	Throughput Rating
169-2	TH-62	I-394	1,045	2,504	Moderate
169-3	Minnesota River	TH-62	1,468	5,941	High
35E-1	Maryland	TH-36	2,619	6,431	High
35E-2	TH-36	CR E	1,210	1,404	Moderate
35E-3	CR E	CSAH 14	729	1,245	Moderate
35W-1	42nd St.	Minneapolis CBD	256	1,504	Low
35W-2	University	TH-280	1,567	3,804	High
35W-3	TH-280	95th Ave	691	1,426	Moderate
36-1	I-35W	I-35E	573	1,509	Moderate
36-2	I-35E	I-694	320	798	Low
494-1	I-394	I-94 /I-494	781	1,999	Moderate
494-2	TH-212	MSP Airport	1,448	1,057	Moderate
694-1	I-35W	I-35E	1,895	3,853	High
694-2	I-94	US 61	810	726	Moderate
77	CSAH 42	I-494	1,075	4,434	High
94-1	TH-101	I-94 /I-494	304	801	Low
94-2	Cedar	Marion	1,674	2,351	High
94-3	St. Paul CBD	I-694	359	784	Low

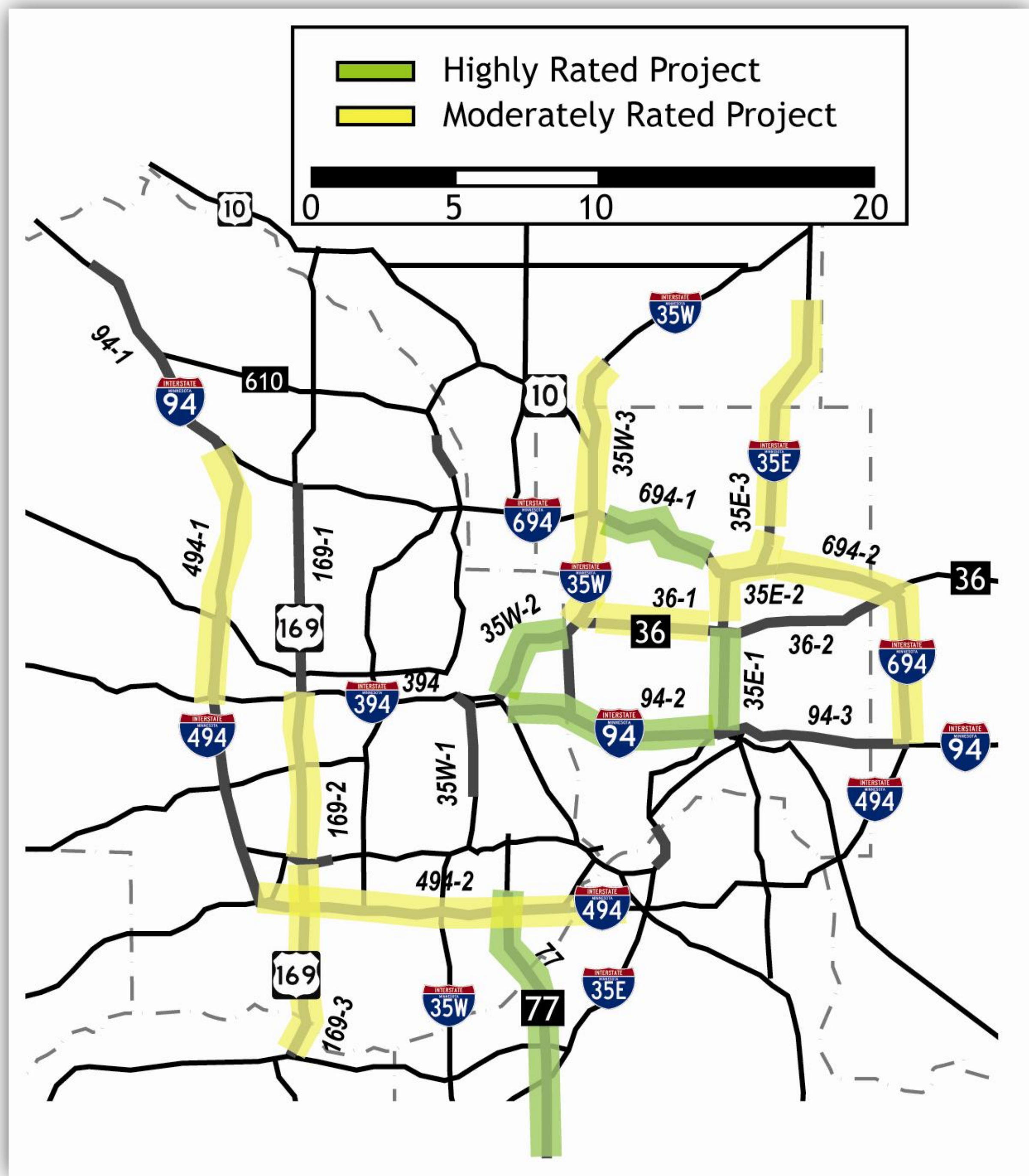


FIGURE 9: MANAGED LANE PERFORMANCE ASSESSMENT: THROUGHPUT (MAP)

OPTIMIZATION

Positive findings for improvements in travel time reliability are largely correlated with congested facilities and peak periods. As such, the reliability measure would best be examined as change in delay hours, separated by lane type (managed lane vs. general purpose lane). As the managed lane conditions will be congestion-free, then the real comparison points are: 1) between build / no-build conditions in the general purpose lanes, and, 2) vehicular delay differences between managed lane / general purpose lanes. Appropriate measures of effectiveness are vehicle minutes of delay by trip categorized by facility type. Peak period separation may accentuate the differences. Examining the potential benefit (as proxied by mileage normalization) that a project can provide for travel time reduction, vehicle hours of delay reduced per centerline mile were examined. This offers an easy-to-describe means of articulating benefits from the project. The reduction in congested VMT shows an unscaled performance measure, which provides a measure of the total magnitude of the intended improvement and examines (throughout the network) how many sections of roadway are relieved by the project. It should be noted that the optimization measures of effectiveness, with their emphasis upon high-volume facilities, tend to favor suburban routes with high rates of single-occupant vehicle mode share. As a result, corridors that may be effective at improving transit travel times and enhancing person-carrying capacity of buses will not necessarily be reflected in these results. The results of all three analyses are shown in Table 9 and Figure 10.

TABLE 9: MANAGED LANE PERFORMANCE ASSESSMENT: OPTIMIZATION

Corridor	From	To	Congested VMT Reduced	Peak Delay / Trip Reduced	Average Trip Time Reduced	Optimization Rating
169-2	TH-62	I-394	195,729	0.11	4.57	Moderate
169-3	Minnesota River	TH-62	22,035	3.38	3.20	Moderate
35E-1	Maryland	TH-36	88,251	0.88	1.79	Moderate
35E-2	TH-36	CR E	131,531	0.43	1.67	Low
35E-3	CR E	CSAH 14	106,631	0.46	2.04	Low
35W-1	42nd St.	Minneapolis CBD	91,109	0.74	2.79	Moderate
35W-2	University	TH-280	91,687	0.30	2.21	Low
35W-3	TH-280	95th Ave	233,879	0.58	2.40	Moderate
36-1	I-35W	I-35E	224,568	0.69	2.16	Moderate
36-2	I-35E	I-694	302,410	0.77	2.58	Moderate
494-1	I-394	I-94 /I-494	96,685	0.55	3.63	Moderate
494-2	TH-212	MSP Airport	183,630	0.90	1.86	High
694-1	I-35W	I-35E	8,615	0.97	1.56	Low
694-2	I-94	US 61	212,827	0.65	2.47	Moderate
77	CSAH 42	I-494	69,211	0.93	1.61	Low
94-1	TH-101	I-94 /I-494	277,055	1.51	4.31	High
94-2	Cedar	Marion	110,646	0.09	1.99	Low
94-3	St. Paul CBD	I-694	35,257	0.12	0.98	Low

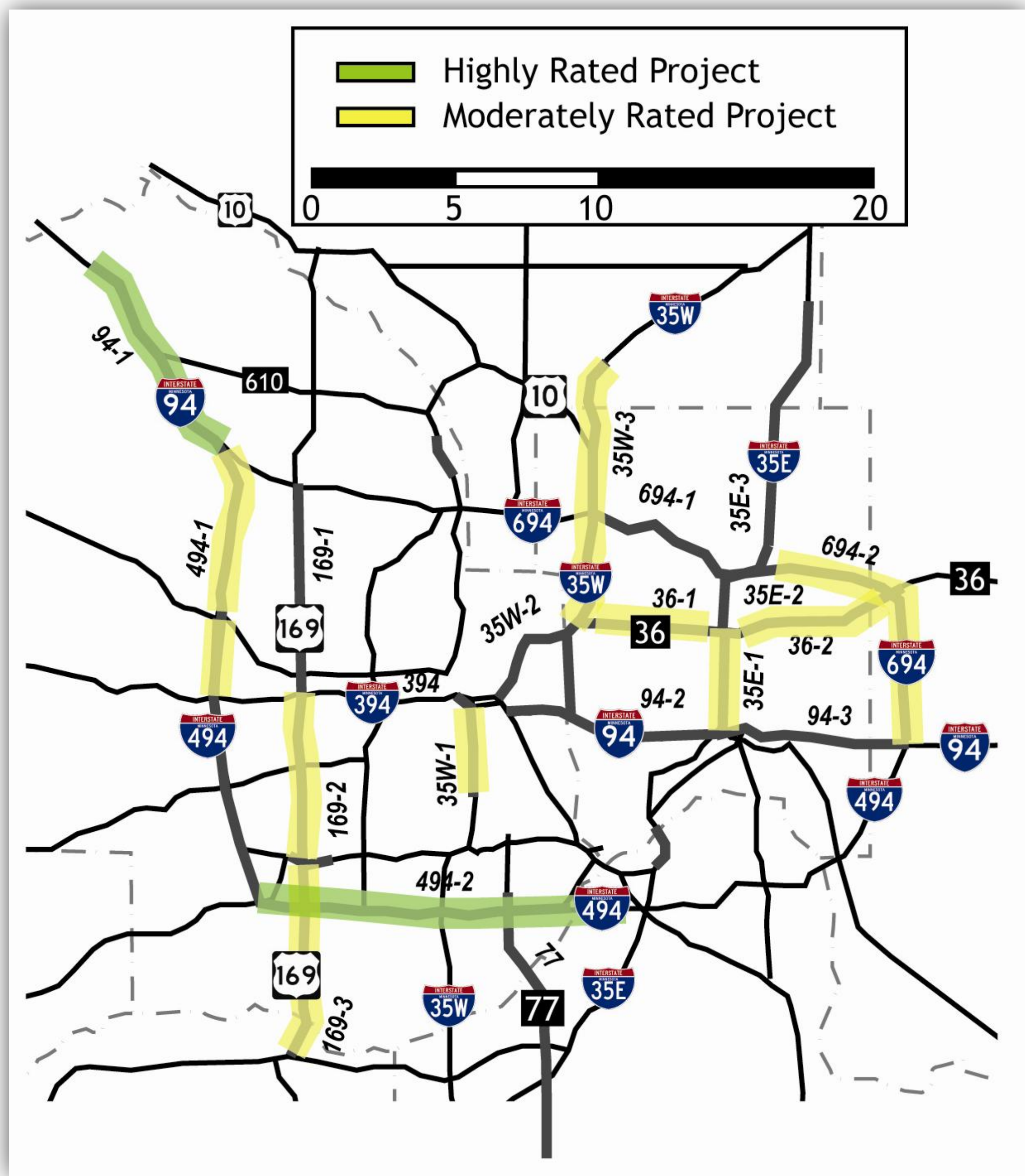


FIGURE 10: MANAGED LANE PERFORMANCE ASSESSMENT: OPTIMIZATION (MAP)

Reduce Single Occupant Vehicle Demand

Reducing SOV demand on the metropolitan highway system was shown with two metrics. The first metric is an increase in transit mode share. The mode choice component of the travel demand forecast model was not included by the Metropolitan Council for this effort. Furthermore, transit service levels (e.g., speeds, fares, headways) were not changed in the build scenarios. Therefore, the resulting trip assignments do not reflect changes in transit service levels that may result from the proposed improvements. However, changes in mode shares result since the level of service will often change as a result of the alternatives' capacity enhancements. This is reflected in the findings.

An additional pivot analysis of mode shift was conducted, evaluating the attractiveness of the capacity enhancements for single occupant vehicles as a percent of overall new trip attraction. In this analysis, a project that attracts more (as a percent) SOV's than HOV's and transit relative to the initial mode distribution rates negatively. Roadways that rate highly in this pivot analysis tend to favor corridors generally lacking in transit service, as the new managed lanes will disproportionately shift travelers to HOV's instead as the mode of choice.

Altogether, these two measures attempt to capture the primary modes for reducing SOV mode share: transit and HOV use increases. These results are shown in Table 10 and Figure 11.

TABLE 10: MANAGED LANE PERFORMANCE ASSESSMENT: SOV DEMAND REDUCTION

Corridor	From	To	Transit Mode Share Change	SOV Use Change	Demand Reduction Rating
169-2	TH-62	I-394	0.40%	-0.75%	Moderate
169-3	Minnesota River	TH-62	0.70%	-1.23%	Moderate
35E-1	Maryland	TH-36	0.20%	-8.27%	Low
35E-2	TH-36	CR E	0.30%	-3.75%	Moderate
35E-3	CR E	CSAH 14	0.30%	-1.81%	Moderate
35W-1	42nd St.	Minneapolis CBD	0.30%	2.47%	Moderate
35W-2	University	TH-280	0.40%	-3.99%	Moderate
35W-3	TH-280	95th Ave	0.30%	-3.01%	Moderate
36-1	I-35W	I-35E	0.30%	-5.66%	Moderate
36-2	I-35E	I-694	0.40%	-0.17%	Moderate
494-1	I-394	I-94 /I-494	0.70%	3.93%	High
494-2	TH-212	MSP Airport	0.20%	-9.69%	Low
694-1	I-35W	I-35E	0.60%	1.12%	High
694-2	I-94	US 61	0.20%	0.43%	Moderate
77	CSAH 42	I-494	0.10%	-7.06%	Low
94-1	TH-101	I-94 /I-494	0.50%	7.58%	High
94-2	Cedar	Marion	0.40%	-5.61%	Moderate
94-3	St. Paul CBD	I-694	0.00%	-17.11%	Low

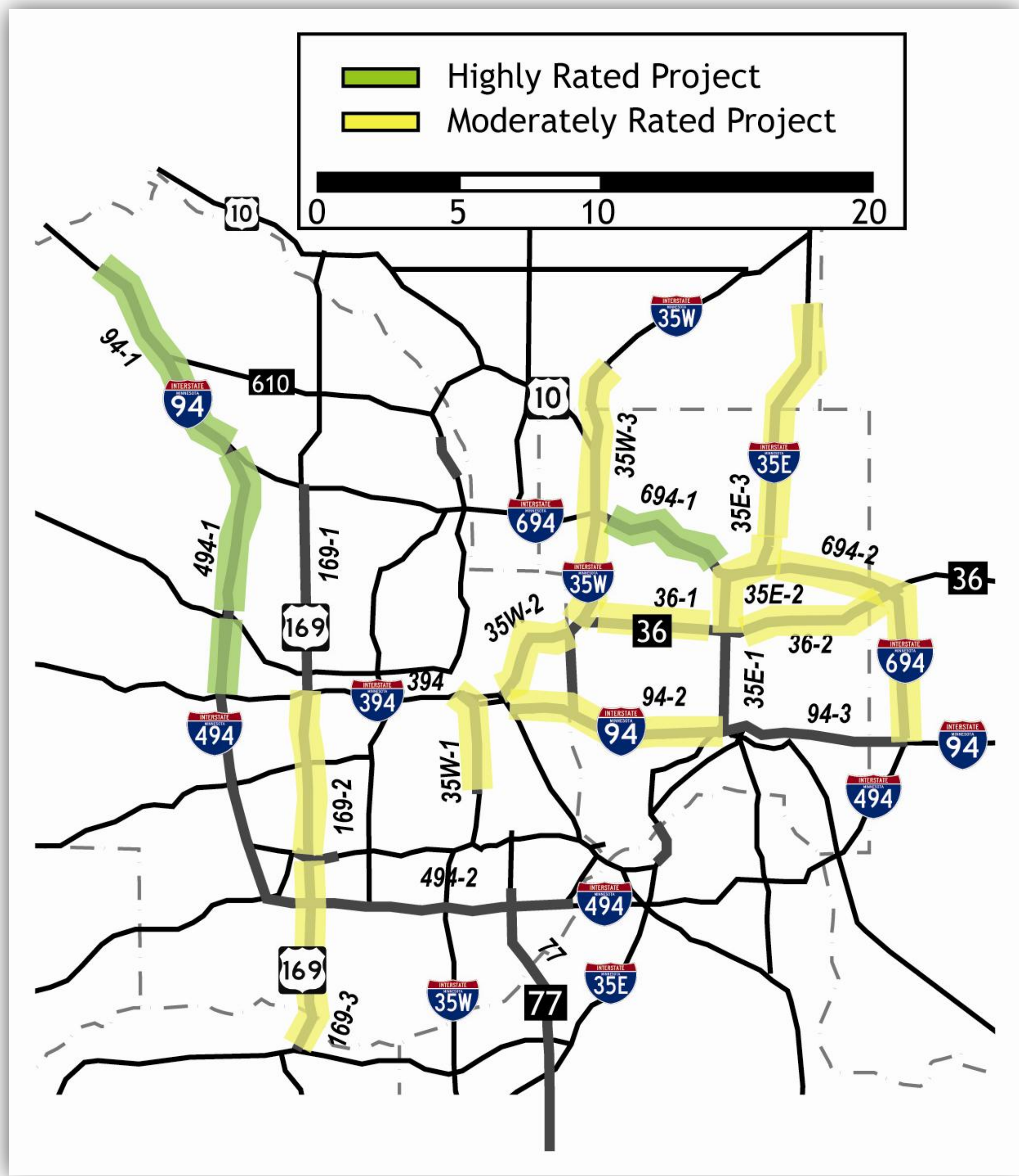


FIGURE 11: MANAGED LANE PERFORMANCE ASSESSMENT: SOV DEMAND REDUCTION (MAP)

Strategic and Affordable Investments

Cost effectiveness calculations constitute an econometric analysis of the annualized value of benefits relative to the capital and operations / maintenance costs to produce the improvement. Benefits are valued as the annualized benefit of travel time reduction, net operational benefits in system costs (minus O&M costs), and operating benefits for the traveler's reduction in delay conditions. Costs involve an annualized estimate of capital construction costs (including managed lane deployment, mill and overlay, grading, drainage, structures, utilities, engineering, escalation, and risk). Any positive finding of 1.0 or higher in the benefit / cost ratio indicates a net beneficial project, shown in Table 11 and Figure 12.

TABLE 11: MANAGED LANE PERFORMANCE ASSESSMENT: COST EFFECTIVENESS

Corridor	From	To	Benefit Cost Analysis	Cost Effectiveness Standard Deviation	Cost Effectiveness Rating
169-2	TH-62	I-394	10.445	0.185305	Low
169-3	Minnesota River	TH-62	7.615	0.135098	Low
35E-1	Maryland	TH-36	19.08	0.338499	Moderate
35E-2	TH-36	CR E	139.575	2.476209	High
35E-3	CR E	CSAH 14	12.165	0.21582	Moderate
35W-1	42nd St.	Minneapolis CBD	21.22	0.376465	Moderate
35W-2	University	TH-280	18.055	0.320315	Moderate
35W-3	TH-280	95th Ave	13.64	0.241988	Moderate
36-1	I-35W	I-35E	38.45	0.682144	High
36-2	I-35E	I-694	43.08	0.764285	High
494-1	I-394	I-94 /I-494	14.43	0.256004	Moderate
494-2	TH-212	MSP Airport	12.07	0.214135	Low
694-1	I-35W	I-35E	16.395	0.290865	Moderate
694-2	I-94	US 61	12.44	0.220699	Low
77	CSAH 42	I-494	9.31	0.165169	Low
94-1	TH-101	I-94 /I-494	17.73	0.314549	Moderate
94-2	Cedar	Marion	9.57	0.169782	Low
94-3	St. Paul CBD	I-694	3.085	0.054731	Low

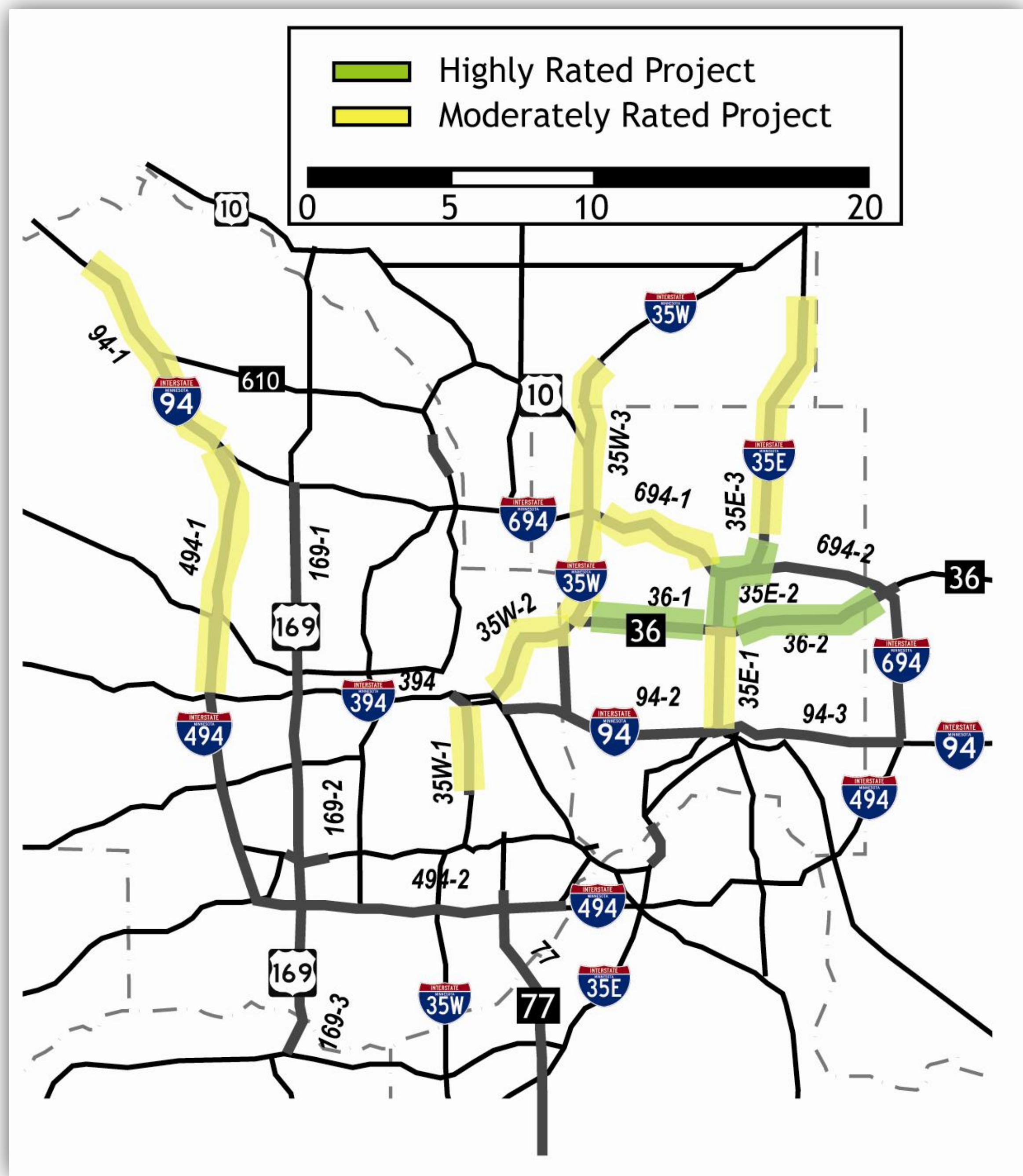


FIGURE 12: MANAGED LANE PERFORMANCE ASSESSMENT: COST EFFECTIVENESS (MAP)

5.0 Prioritization Analysis

Through the course of the MHSIS project development and analysis, the MHSIS project management team in conjunction with the project team determined that select categories of improvement, including arterial-based access management and signalization projects, would best be developed under the context of the Congestion Management and Safety Program (CMSP), a Mn/DOT initiative intended to make short-term, lower-cost improvements to the freeway and arterial systems. Additionally, two classification of projects – interchange closure / consolidation and strategic capacity expansion – were analyzed but set aside from the MHSIS. These facilities will be considered in the 2030 TPP update process, as appropriate.

Project Analysis

Twenty four managed lane projects were analyzed, including two conversions of general purpose lanes (on I-35E and I-494), four asynchronous managed lanes (on I-35E, I-35W I-94, and TH-252), and 18 bi-directional managed lanes. The appendices provide detailed composite analyses of each project.

Some projects were excluded by the project management team from the final analysis, due to low performance metrics across the spectrum of analysis, and, removal from the MnPass System Study Phase 2 (US 169 north of I-394, I-394, and TH-280). Secondly, the conversion projects (originally considered for lane balancing reasons) were excluded from the final analysis, due to policy maturation as a result of the MnPass System Study Phase 2. For these two projects, the identified segments would continue as expansion projects instead. Finally, the small-size asynchronous were forwarded to the CMSP for consideration and inclusion as appropriate. Overall, the asynchronous projects rate highly for performance due to their short length (with corresponding low cost), and targeted implementation. In all four cases, these projects are envisioned as providing outbound capacity in bottleneck areas.

In the Table 12 and Figure 13 summary, the overall performance rating of the managed lane corridors indicate which improvements best correspond with the objectives of the MHSIS for assumed potential implementation by 2030. Corridors with a rating of "High" or "Moderate" are likely in keeping with the guiding principles of the MHSIS. By contrast, those with a "Low" rating may not correspond from a performance perspective. Although some facilities may not be appropriate for the short term (2030), these managed lanes may work for the longer term (2030 – 2060), and as a result remain within the long-term vision of the managed lane network for the region.

TABLE 12: MANAGED LANE PRIORITIZATION SUMMARY

Corridor	Throughput	Optimization	Demand Reduction	Cost Effectiveness	Transit Suitability	Investment Parity	Opportunity	Composite
169-2	Moderate	Moderate	Moderate	Low	High	Moderate	High	**Moderate**
169-3	High	Moderate	Moderate	Low	Moderate	High	High	**Moderate**
35E-1	High	Low	Low	Moderate	Moderate	High	High	**High**
35E-2	Moderate	Low	Moderate	High	Low	Low	Moderate	**Moderate**
35E-3	Moderate	Moderate	Moderate	Moderate	Low	Moderate	Moderate	**Low**
35W-1	Low	Moderate	Moderate	Moderate	High	High	High	**High**
35W-2	High	Low	Moderate	Moderate	High	Moderate	Moderate	**Moderate**
35W-3	Moderate	Moderate	Moderate	Moderate	High	Moderate	High	**High**
36-1	Moderate	Moderate	Moderate	High	High	High	High	**High**
36-2	Low	Moderate	Moderate	High	High	Low	High	**Moderate**
494-1	Moderate	Moderate	High	Moderate	Low	High	Low	**Moderate**
494-2	Moderate	Moderate	Low	Low	Low	Moderate	Low	**Low**
694-1	High	Low	High	Moderate	Low	High	High	**High**
694-2	Moderate	Moderate	Moderate	Low	Low	High	Low	**Low**
77	High	Low	Low	Low	High	Moderate	High	**Moderate**
94-1	Low	High	High	Moderate	Moderate	Moderate	Moderate	**Moderate**
94-2	High	Low	Moderate	Low	High	Moderate	High	**Moderate**
94-3	Low	Low	Low	Low	High	Moderate	Moderate	**Low**

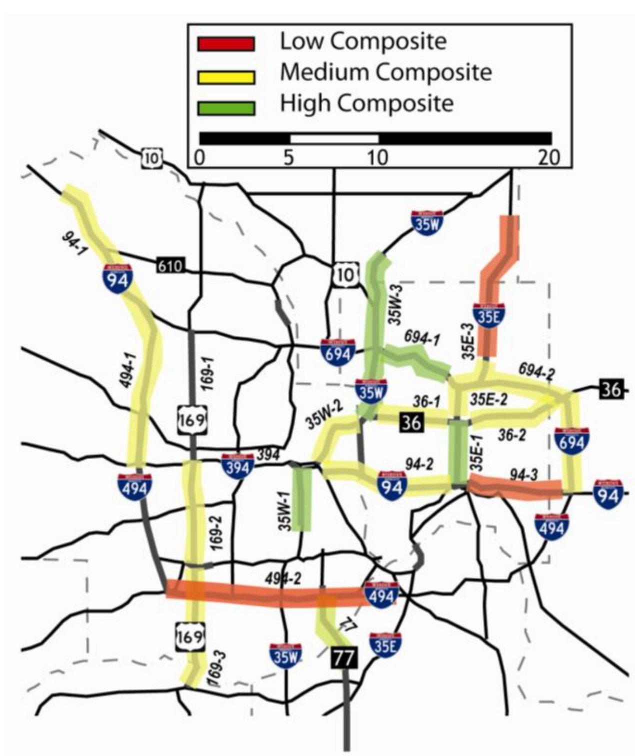


FIGURE 13: MANAGED LANE PRIORITIZATION SUMMARY

2030 MANAGED LANES PLAN

Of capacity expansion projects, certain managed lane projects stand-out as advantageous for action within the 2010 – 2030 timeframe:

- I-35E, from downtown St. Paul to north of I-694 (35E-1 and 35E-2). Although not as high a performer as other managed lane corridors, there are extenuating circumstances that advance this corridor. First, the Cayuga Bridge reconstruction project provides an opportunity to cost effectively add managed lanes. Furthermore, the reconstructed interchange at I-694 has abundant pavement availability, allowing for managed lane expansion in this segment without substantial additional cost. Together, this permits a greater return on investment from the reconstruction activities. Second, this section of the metropolitan highway system rates well for parity purposes (addressing previously planned facilities in the long range plan).

  The MnPass System Study Phase 2 identified the section including 35E-1 as a good performer, with a moderate benefit-to-cost ratio and up to 17 percent capital cost recovery from tolling. However, the segment comprising the same limits as 35E-2 and 35E-3 were not as strong of performers, with a low benefit-cost ratio and only two percent of capital cost recovered by tolling.

  It should also be noted that the MnPass System Study Phase 2 proposes extending the I-35E managed lanes south of the 35E-1 segment limit into downtown St. Paul with a direct connection ramp. Based upon the finding from the MnPass System Study Phase 2 and the overall positive findings from the MHSIS, this study adopts the MnPass System Study Phase 2 limits for the corridor (including direct connection) as the preferred corridor. The cost estimate table, below, incorporates the MnPass System Study Phase 2 estimate, not the initial MHSIS limits as initially developed.

- I-494, from I-394 to I-94/I-494 interchange (494-1). The I-494 corridor would significantly benefit from the implementation of managed lanes, as evidenced from the modeling activities. Furthermore, this corridor has a high rating for investment parity, based upon prior commitments in the long range plan. Finally, the corridor helps the I-394 MnPass lanes constitute the beginning of a system, with the possibility to serve managed lane trips from the south to northwest Metro across much of the system. The key limitation of this corridor will be the likely lack of connectivity between the I-394 MnPass lanes and the I-494 managed lanes, although this could be addressed in the future if the interchange must be reconstructed. However, given the strength in performance and moderately rated cost effectiveness, this corridor's opportunities outweigh its weaknesses.

  The MnPass System Study Phase 2 findings indicate that the corridor comprising limits between I-394 and I-94 as a moderate-to-high cost-to-benefit performer. Although the corridor's capital cost for construction is low, the cost recovery from tolling is estimated at six percent by the MnPass System Study Phase 2.

- I-35W, from downtown Minneapolis to 95th (35W-1 and 35W-2). I-35W north is one of the strongest transit corridors for the managed lane system, and deserves special consideration here. In addition to its transit suitability, this corridor has moderate-to-high ratings for performance, including throughput, optimization and SOV travel reduction. The ability to serve regional and inter-regional trips on the managed lane system is high, with close connections to I-394 and I-35W to the south. Finally, given the presence of existing bus-only-shoulder operations, the ability to convert this facility to managed lanes is strong.

  Like I-35E, the MnPass System Study Phase 2 is developing a direct connection concept for downtown Minneapolis. With this connection, the cost effectiveness ratio was a moderate performer; however, the capital cost recovered from tolling approached 16 percent as estimated by the Study. Furthermore, the MnPass System Study Phase 2 shows high performance improvement from this corridor. Thus, both studies confirm the appropriateness of this corridor's inclusion within the 20 year development horizon.

- TH-36, between I-35E and I-35W (36-1). TH-36 held moderate ratings throughout all performance criteria. This segment also performs well for transit suitability, investment parity, and cost effectiveness. Finally, this segment is programmed for interchange work on Lexington and Rice, providing an efficiency opportunity to address managed lanes as it pertains to these structures. As a result, TH-36 is recommended for managed lanes development in the MHSIS. However, one crucial concern with TH-36 is its connections with I-35W an I-35E. Without direct connection ramps, which are cost prohibitive without appropriately sized accompanying benefit, the termini for TH-36 median-based managed lanes would require weaving to a right-side ramp in both conditions. In the case of westbound TH-36 to southbound I-35W, this movement would likely severely curtail corridor operations. Additional simulation study is recommended to determine the operational impacts of managed lanes on this corridor without direct connections. In the next 20 years, it may be possible to implement asynchronous managed lanes on this corridor, featuring an eastbound-only treatment. Again, additional study should evaluate the effectiveness of an asynchronous treatment if a bi-directional treatment cannot be affirmed.

  The MnPass System Study Phase 2 evaluated the asynchronous treatment for TH-36. Under this analysis, performance was not significantly enhanced with this project, and the project yielded a low-to-moderate cost effectiveness rating. This finding confirms the concerns on the asynchronous design of the project. However, the opportunity to develop the lane at lower cost due to programmed improvements may warrant its consideration.

- I-94, between downtown Minneapolis and downtown St. Paul (94-2). The I-94 managed lane project rated well for throughput, but low for optimization primarily due to the constraints imposed upon the corridor by the Lowry Hill tunnel and the Capitol interchange. Furthermore, the need to replace structures in the corridor yields an elevated cost versus other facilities in the region, thereby depressing the corridor's overall cost effectiveness rating. Pending deployment of ATM in the corridor may assist in addressing some of the corridor's traffic effects, while providing for enhanced bus operations. Furthermore, a parallel light rail transit facility will soon open, providing a corridor alternative for transit riders. All of these conditions lend to a conclusion that I-94 should remain a medium priority for managed lane development, with an understanding that upcoming opportunities may arise for reconstruction purposes that can positively affect the return on investment in this corridor.

The MnPass System Study Phase 2 found this project to be a good performer from a revenue generation perspective (25 percent cost recovery) and moderate performer for cost effectiveness. However, the Study also highlights this corridor as a high risk, making its inclusion in the 20-year MHSIS also risky. If additional study finds the cost reductions and traffic operations as projected by the MnPass System Study Phase 2 to be of merit, this project fits within the established budget due to revenue generation potential.

The MHSIS Project Management Team has developed a working budget estimated at approximately $450 to $500 million (2010 dollars) for the years 2014 – 2020 for deployment on managed lane facilities, and an additional $50 to $100 million anticipated for ATM deployment. As ATM as a concept has been refined as a supplement to managed lane deployment, an independent budget may be counterproductive. The consolidated budget is estimated at approximately $500 to $600 million. As such, the following estimates include the deployment of ATM as a complementary strategy to managed lanes. Given managed lanes and ATM deployment share some infrastructure, the specific cost for ATM is reduced from $2.0 M per mile to $1.6 M per mile. Using cost estimates refined by the MnPass System Study Phase 2 for the early action corridors (where available), this yields a simple division of expenditure (2010 dollars) in Table 13.

TABLE 13: COST ESTIMATE BY 2030 MANAGED LANE CORRIDOR

Project	Construction ($M 2010)	ATM ($M 2010)	Total (inc. risk) ($M 2010)
I-35E	$75	$12	$120
I-494	50	11	61
I-35W	165	24	255
TH-36 (est. asynch.)	16	6	28
I-94	88	15	103
TOTAL	$ 394 M	$ 68 M	$ 567 M

Additional facilities that are recognized for the long-term (2030 – 2060 timeframe) implementation include:

- TH-77, between 141st Street and TH-62. The TH-77 corridor is currently under study by Mn/DOT for managed lane feasibility, with a planned Bus Rapid Transit lane to be constructed in the vicinity of the Apple Valley Transit Center in the next few years. Although the performance modeling did not rate favorably for the corridor, this is due to the length of the modeled facility. Current planning activities indicate a shorter segment may be feasible and meet project needs. In order to avoid biasing the results of this planning study, the MHSIS is avoiding a prioritized determination of feasibility for 2030, but has included the facility for planning purposes.

  The MnPass System Study Phase 2 included the project in its analysis of a northbound lane. This analysis indicates that the asynchronous managed lane would have a moderate performing benefit-to-cost ratio and low cost of construction. However, this facility would also yield relatively low rates of revenue.

- I-94, between TH-101 and I-494 (94-1). The market for this project may be significantly affected by the completion of TH-610. Managed lane implementation may be warranted in the future, but 2030 performance metrics indicate the usefulness of managed lanes for person throughput may be constrained. It is recommended to evaluate the efficacy of this project as an extension of I-494 managed lanes (upon deployment) and post-completion of TH-610.

- I-694, between I-35E and I-35W (694-1). The I-694 segment between I-35W and I-35E rates highly for performance metrics, including throughput and SOV demand reduction. Additionally, this corridor rates well for investment parity purposes, based upon previous commitments in the 2030 plan, and rates moderately well for cost effectiveness. The benefit-cost calculation, though, did not account for programmed improvements to the I-35W / I-694 interchange as well as additional investment on I-694 in this segment. As a result, this cooperative opportunity would benefit the implementation of managed lanes in this segment. Additional study should assess the specific value of bi-directional and asynchronous (westbound only) treatments, especially in light of potential asynchronous treatment on TH-36 in the opposing direction.

- US 169, between TH-62 and the Minnesota River (169-3). Managed lanes on US 169 offer moderately strong performance metrics, but poor cost effectiveness due to the limited market for this facility relative to cost. As population expands in the southwest Twin Cities, this facility may become more necessary in order to enhance mobility options from the growth sectors to the urbanized area. Planned improvements to the I-494 and US 169 interchange provide an opportunity to reduce the cost of development of managed lanes. At a minimum, it is recommended that this interchange effort consider the future implementation of managed lanes on not only US 169, but also I-494 in the design of the facility.

  The MnPass System Study Phase 2 determined this corridor had a very high benefit-to-cost ratio and revenue generation (21 percent cost recovery from tolls). However, as this facility does not serve regional trips and does not comprise a system, it is inappropriate to include the facility as a part of the 20-year planning horizon for the MHSIS.

- US 169, between TH-62 and I-394 (169-2). If an opportunity for cost reduction is available for US 169 in this segment, the performance metrics suggest a productive corridor for managed lanes. Key questions concern the connectivity between I-394 and I-494. Without an opportunity for cost reduction, this project is not recommended for the 50-year horizon.

- I-494, between I-394 and Minneapolis / St. Paul airport (494-2). Whereas I-494 in the vicinity of I-35W has been designated as a potential strategic capacity expansion, it may be more productive to consider this segment as a managed lane corridor and extending the facility to MSP airport, which has acceptable performance metrics. However, given the high cost of this project, only an opportunistic perspective should be use for long-term development.

  Like I-94 between the two cities, the MnPass System Study Phase 2 found this project to be a good performer from a revenue generation perspective (25 percent cost recovery) and high performer for cost effectiveness. However, the Study also highlights this corridor as a high risk, making its inclusion in the 20-year MHSIS also risky. If additional study finds the cost reductions and traffic operations as projected by the MnPass System Study Phase 2 to be of merit, this project could move into the 20-year horizon.

- TH-36, between I-35W and I-694 (36-1 and 36-2). Assuming TH-36 has an asynchronous development in the 20-year plan, the 50-year horizon suggests a bidirectional deployment may be warranted if connections to I-35W and I-35E can be resolved. Additionally, opportunities to extend the managed lane corridor to I-694 may be viewed favorably based upon performance estimates. This should be viewed opportunistically for cost reduction.

- I-694, between I-94 and I-35E (694-2). This segment of I-694 had moderate levels of performance benefit associated with managed lanes; however, the cost of development yielded low cost effectiveness relative to those benefits. As a result, the region should review this corridor in the perspective of opportunity for cost reduction.

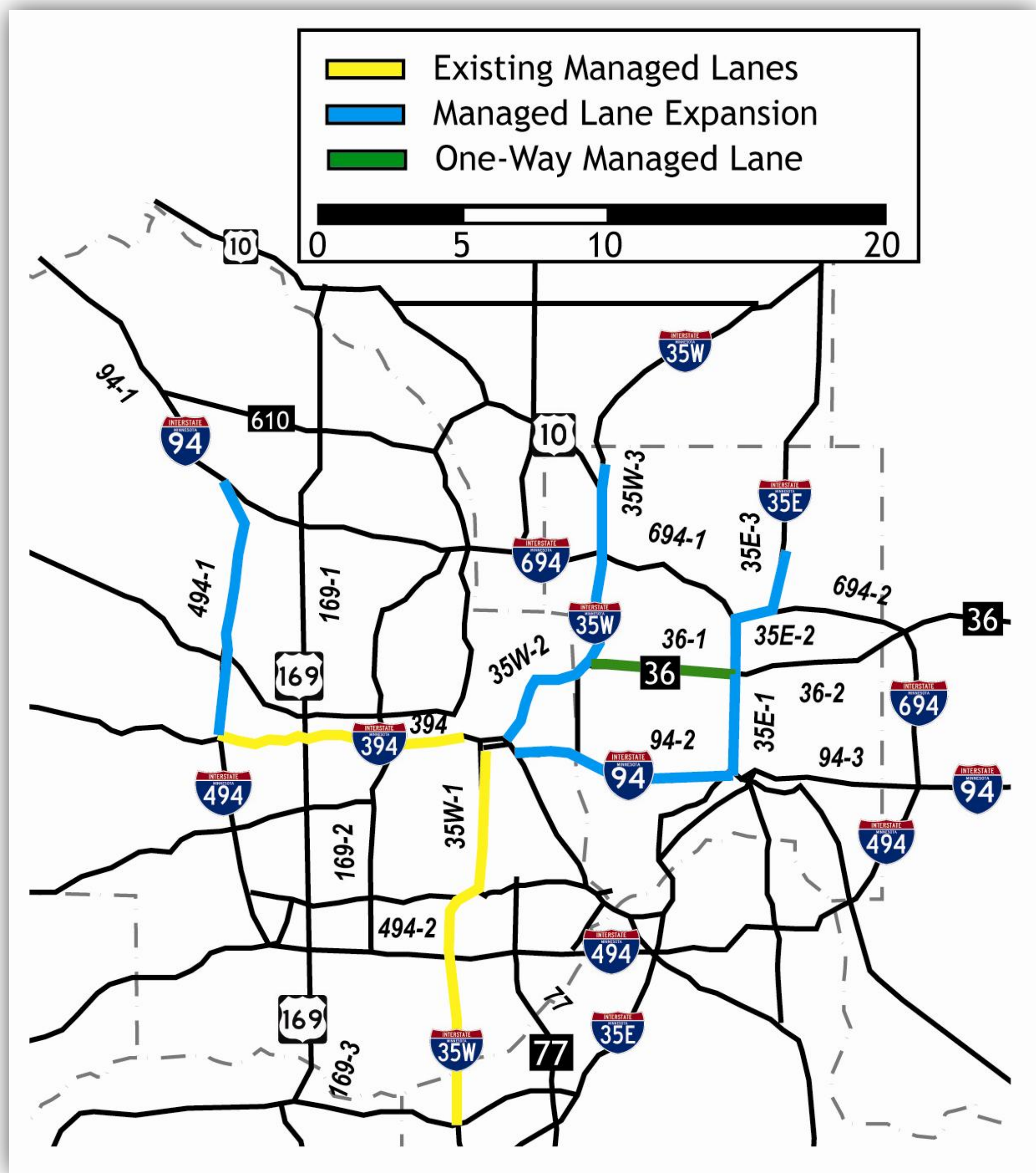


FIGURE 14: 20-YEAR MANAGED CAPACITY RECOMMENDED PROJECTS

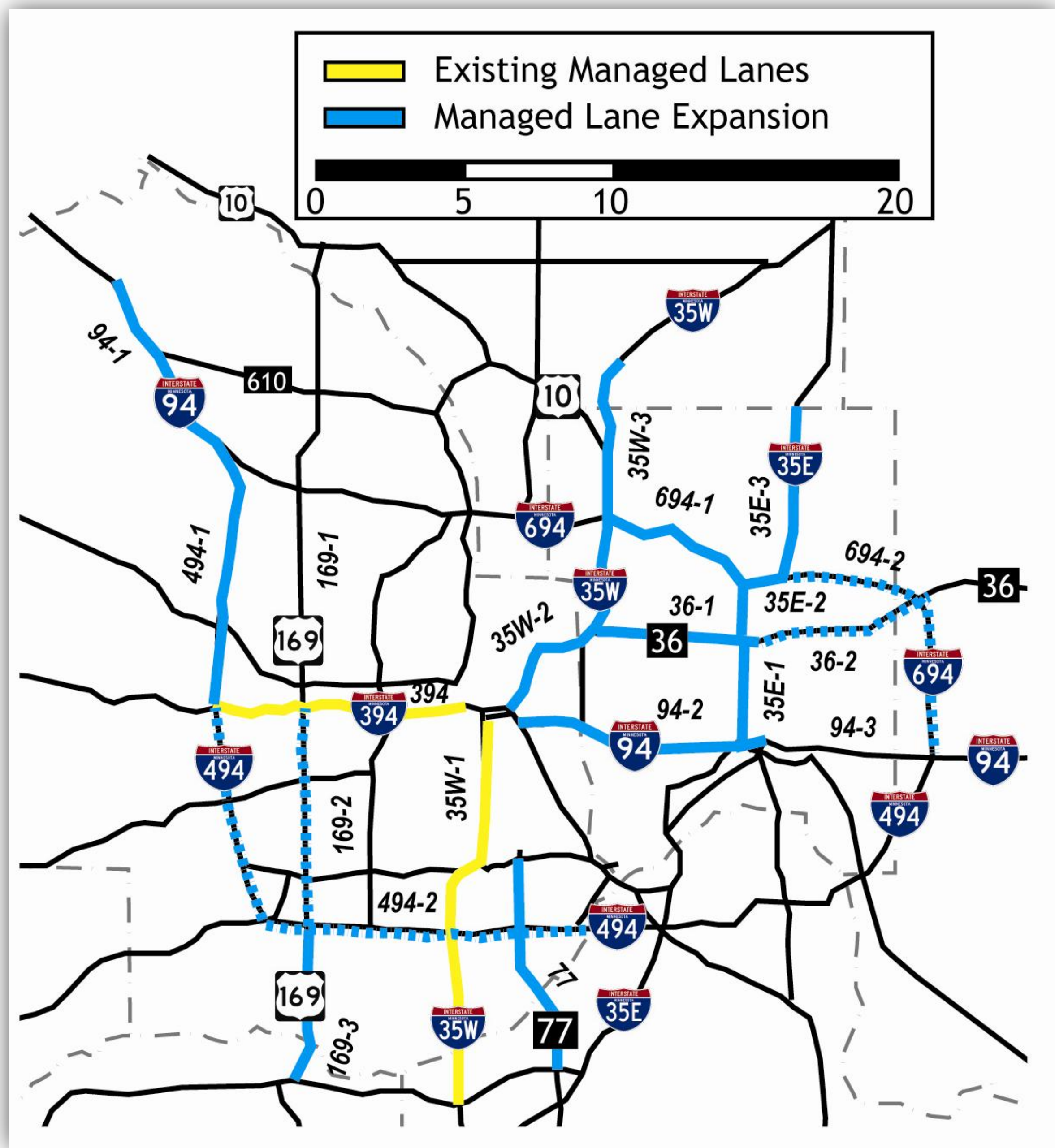


FIGURE 15: 50-YEAR MANAGED CAPACITY RECOMMENDED PROJECTS

6.0 OTHER CONSIDERATIONS

The MHSIS represents the first stage in a series of planning, technical, institutional and financial analyses that will successively lead to implementation of the regional managed lanes network and lower-cost / high benefit improvements in the Twin Cities. In addition to the ongoing MnPass System 2 effort, MHSIS study findings should be considered within the outreach and technical development for the 2030 Metropolitan Transportation Policy Plan (TPP). Additional data and studies will be needed on a corridor-by-corridor basis to identify the physical attributes and operational characteristics of each managed lanes corridor. Phasing of improvements will be important in achieving the highest potential for early success and in minimizing impacts and risk associated with managed lanes implementation. Phasing of improvements also will consider the programming of other projects in the study corridors to the extent possible, yielding positive return-on-investment.

Given the expanding inter-regional nature of the managed lanes, and, reliance upon managed lanes as the primary capacity expansion tool, a formal interagency process and mechanism should be established to ensure coordination is maintained throughout all facets of planning, data collection, design, forecasting, operations, and revenue distribution. The formal group (which may involve continuation of established procedures between the Metropolitan Council and Mn/DOT) should focus on issues such as determining the pricing/vehicle eligibility requirements for managed lanes as consistent with the 2030 TPP objectives, collecting data on travel behavior characteristics and managed lanes use, and identifying financing strategies to cover the operations and maintenance costs of the system, so that the regional plan is unaffected.

The advancement of MnPass on the MHSIS corridors will require more detailed operations analysis and refined engineering design of potential managed lanes at the individual corridor level. Work elements that could be undertaken in these corridor studies include, but likely are not limited to:

- Revised demand projections. The focus of this work will be to revise the demand estimates for managed lanes treatments along a corridor based on updated design and phasing assumptions, and incorporating additional managed lanes in the model as each is developed and implemented (the MHSIS treated each corridor in isolation from each other). The effort will provide for feedback between corridor-specific pricing models (such as that conducted for the MnPass System Study Phase 2) and the regional travel demand model. The task also would include traffic simulation modeling to evaluate potential bottlenecks / weaving at facility termini and identify possible mitigation strategies. This is particularly critical for TH-36 and a few other select facilities.

- Revenue estimates and potential tolls. The updated demand forecasts will generate estimates of traffic, travel behavior and revenue for MnPass priced managed lanes. This task will identify optimal tolls for each proposed facility and the corresponding revenues which could be generated from these tolls. The optimal toll rates will be designed to manage demand, as is currently performed on I-394 and I-35W and corresponds with existing policy. If desired by new policy, optimal toll rates could also be designed to minimize the commitment of non-project revenue to pay construction costs and/or bonds.

- Preliminary engineering, interim design, and concept of operations. This effort would include detailed operations analysis and designs based on more detailed planning and engineering. Design considerations would address the feasibility of implementing the ATM-dependent design alternatives. This task would include capital cost estimates based on the approved designs. Operational issues would be addressed based on the managed lanes treatment being considered for each corridor, followed by estimating corresponding O&M costs. This task also would involve identification of cost-effective enhancements such as direct access ramps and transit park-and-ride facilities in order to maximize the benefits of the Managed Lanes treatment. To illustrate the type of work to be undertaken in this portion of the study, the following issues or questions would be explored and answered:
    - What operational issues would establish project limits?
    - Are there special enforcement needs or ability to place monitoring areas?
    - What are the incident management needs?
    - For tolling, how many tolling zones and installations are envisioned for each direction?
    - What will be the preferred delivery and maintenance approach for tolling systems?
    - Are there needs for traffic detection in the pavement? Will cameras be employed?
    - What other Intelligent Transportation Systems (ITS) should be considered?

- Financial feasibility and phasing. This effort will involve a comparison of forecasted toll revenues and costs attributable to a priced facility over its life cycle. A comprehensive cash flow analysis will match revenue/funding sources and financing with capital and O&M costs to identify potential funding gaps and possible phasing of improvements. The timing of other programmed improvements in the corridor and their impacts on the proposed project would be considered as part of this work element. Other factors such as the planned implementation of supportive transit services or corridor maintenance/improvement projects should also be considered in phasing decisions.

Given the reliance of the MHSIS on priced-managed lanes for capacity development, it is important to recognize that a managed lane system will generate disproportionate revenues on a corridor by corridor basis relative to cost. A decision-making and consultation structure should be developed for allocating these revenues. The consultation structure would include Mn/DOT, Metropolitan Council, city and county agencies in addition to possible managed lanes operating partners (if pursued as a public-private partnership). The group could establish strategies when 1) annual revenues do not meet operating costs, 2) costs and revenues are equal, and 3) yearly revenues exceed O&M costs.

GLOSSARY

- AASHTO: American Association of State Highway and Transportation Officials
- ARC: Atlanta Regional Commission.
- ATM: Active Traffic Management. ATM is a package of intelligent transportation systems strategies that are specifically oriented towards improving safety and operational performance on managed freeway corridors.
- BOS: Bus Only Shoulders. BOS operations, predominant in the Minneapolis / St. Paul region, allow buses to use right-side shoulders during certain conditions.
- BRT: Bus Rapid Transit. BRT provides for express bus services within highway-based fixed guideways, often using inline stations.
- Caltrans: California Department of Transportation.
- CCTV: Closed Circuit Television
- CMA: Congestion Management Agencies (California). CMA's are county-based planning, development, and implementation agencies for highway capacity.
- CRD: Congestion Reduction Demonstration. The CRD is an FHWA program designed to showcase managed lane projects' ability to reduce congestion.
- EIR: Environmental Impact Record. The EIR follows the successful completion of the environmental process.
- FDOT: Florida Department of Transportation.
- FHWA: Federal Highway Administration.
- FPI: Freeway Performance Initiative (San Francisco / Oakland). The FPI is a systemwide study and implementation plan for operations and management strategies in the San Francisco Bay Area.
- FTA: Federal Transit Administration.
- GDOT: Georgia Department of Transportation.
- GPS: Global Positioning Satellite system.
- GRTA: Georgia Regional Transportation Authority.
- HCTRA: Harris County Toll Road Authority (Houston).
- HOT: High Occupancy Toll. HOT lanes allow access to fixed guideways, typically reserved for buses and carpools, for toll-paying single occupant vehicles.
- HOV: High Occupancy Vehicle. An HOV typically connotes a carpool, with HOV-2 indicating a 2-person carpool and HOV-3+ indicating 3-or-more person carpool. HOV lanes allow access to fixed guideways, typically reserved for buses , for carpools.
- ITS: Intelligent Transportation Systems. ITS is a package of technologies oriented towards enhancing the operational effectiveness of the highway system.
- LRT: Light Rail Transit. LRT is an electrically-powered surface rail transit which operates in both exclusive and/or shared right of way.
- MetCouncil: Metropolitan Council.
- Mn/DOT: Minnesota Department of Transportation.
- MPH: Miles Per Hour (speed).
- MPO: Metropolitan Planning Organization.
- MTC: Metropolitan Transportation Commission (San Francisco / Oakland).
- NCHRP: National Cooperative Highway Research Program.
- O&M: Operations and Maintenance.
- P&R: Park and Ride.

- PPP: Public Private Partnership. In the context of this study, a PPP is a contractual relationship between various public and private sector entities towards the development and operations of transportation infrastructure and/or services.
- PSRC: Puget Sound Regional Council.
- ROW: Right of Way.
- RTC: Regional Transportation Commission (Dallas - Ft. Worth).
- RTP: Regional Transportation Plan. The RTP is another way of entitling a long range transportation plan.
- SOV: Single Occupant Vehicle. An SOV connotes only one person (the driver) per vehicle.
- TCRP: Transit Cooperative Research Program.
- TDM: Travel (Transportation) Demand Management. TDM strategies aim to reduce the demand for highway capacity through encouraging greater utilization rates of carpools, transit, non motorized methods of travel, and alternative work arrangements (such as telework).
- TIP: Transportation Improvement Program.
- TOD: Transit Oriented Design.
- TPP: Transportation Policy Plan. The TPP is the Minneapolis / St. Paul region's long range transportation plan.
- TSM: Transportation System Management. TSM strategies aim to improve the operational efficiency of road and highway systems.
- TTI: Texas Transportation Institute.
- TxDOT: Texas Department of Transportation.
- UPA: Urban Partnership Agreement. Like the CRD program, the FHWA UPA program demonstrates the effectiveness of congestion pricing and transit strategies in reducing congestion in partner communities.
- USDOT: U.S. Department of Transportation.
- VMT: Vehicle Miles Traveled.
- WSDOT: Washington State Department of Transportation.

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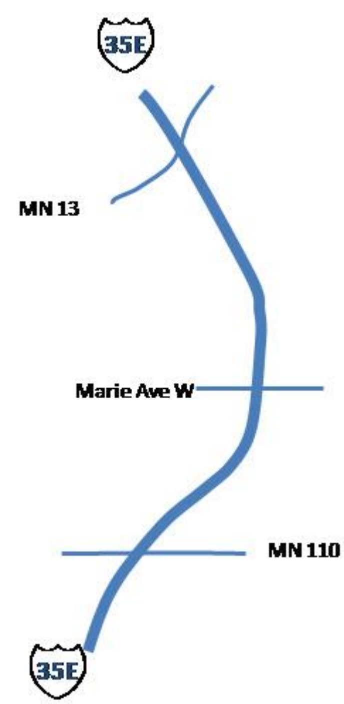
APPENDIX A: DETAILED CORRIDOR EVALUATION SUMMARIES

Project 1B: I-35E

Type	Asynchronous
Limits	TH-110 to TH-13
Lane Miles	.92
Cost Estimate	$5,733,000 (low) - $13,481,000 (high)
Cost Risk	.15 (low) - .25 (high)

Managed Lanes Type, Geometric and Other Considerations: Managed lane expansion, adding a median based managed lane in southbound direction only. Geometric areas of concern are: widen bridge over Marie Avenue W.

Project Metrics	2030
Vehicle Miles of Travel	6,529,742 (build total) - 17,752 (change from no-build)
Vehicle Hours of Travel	220,927 (build total) - 3,257 (change from no-build)
Vehicle Hours of Delay	98,903 (build total) 2,845 (change from no-build)
Vehicular Volumes (change from no-build)	508 (total) 553 (per lane mile)
Person Trips (change from no build)	7,510 (total) 8,163 (per lane mile)
Peak Vehicle Trips (change from no build)	512 (total) 557 (per lane mile)



Project 1B (**I-35E**, *from TH-110 to TH-13*)

Measures of Effectiveness	Value	Rank (of 24)
Throughput		
Daily new vehicles per lane mile	553 (vehicles)	18
Daily new persons per lane mile	8,163 (persons)	1
	Rating: **Moderate**	
Optimization		
Daily reduction in congested VMT	33,872.0 (miles)	21
Daily peak hours of delay per trip reduced	1.28 (minutes)	3
Daily average travel time per trip reduced	3.77 (minutes)	6
	Rating: **High**	
Reduce SOV Demand		
Change in transit mode sure	.001	21
Change in SOV use rate	- .0827	21
	Rating: **Low**	
Cost Effectiveness		
Benefit-cost ratio (mean)	36.38	7
Benefit-cost ratio (standard deviation)	.65	
	Rating: **High**	
Transit Suitability		
2030 planned transit corridor	Express Bus Corridor	
Existing express bus trips	23 (total AM / PM peak periods)	14
Overall transit suitability	No significant need for ramp access, no inline stations	
	Rating: **Moderate**	
Investment Parity		
Overall investment parity	No recent investment; corridor previously identified in 2030 Plan.	
	Rating: **High**	
Opportunity Rating		
Overall opportunity rating	No existing Bus on Shoulder availability; no Bus on Shoulders are planned	
	Rating: **Low**	

OVERALL CONCLUSION: **High**

Project 3A: I-35E

Type	Expansion
Limits	Maryland to TH-36
Lane Miles	6.22
Cost Estimate	$34,256,000 (low) - $44,321,000 (high)
Cost Risk	.25 (low) - .35 (high)

Managed Lanes Type, Geometric and Other Considerations: Managed lane expansion, adding a median based managed lane in each direction. Geometric areas of concern include the Cayuga and TH-36 bridges.

Project Metrics	2030
Vehicle Miles of Travel	18,349,168 (build total) - 8,188 (change from no-build)
Vehicle Hours of Travel	607,796 (build total) - 6,137 (change from no-build)
Vehicle Hours of Delay	287,866 (build total) 7,142 (change from no-build)
Vehicular Volumes (change from no-build)	16,290 (total) 2,619 (per lane mile)
Person Trips (change from no build)	40,002 (total) 6,431 (per lane mile)
Peak Vehicle Trips (change from no build)	12,277 (total) 1,974 (per lane mile)

Project 3A (**I-35E**, *from Maryland to TH-36*)

Measures of Effectiveness	Value	Rank (of 24)
Throughput		
Daily new vehicles per lane mile	2,619 (vehicles)	1
Daily new persons per lane mile	6,431 (persons)	2
	Rating: **High**	
Optimization		
Daily reduction in congested VMT	88,251.0 (miles)	17
Daily peak hours of delay per trip reduced	.88 (minutes)	9
Daily average travel time per trip reduced	1.79 (minutes)	20
	Rating: **Moderate**	
Reduce SOV Demand		
Change in transit mode sure	.002	18
Change in SOV use rate	- .0827	22
	Rating: **Low**	
Cost Effectiveness		
Benefit-cost ratio (mean)	19.08	10
Benefit-cost ratio (standard deviation)	.34	
	Rating: **Moderate**	
Transit Suitability		
2030 planned transit corridor	Express Bus Corridor	
Existing express bus trips	26 (total AM / PM peak periods)	13
Overall transit suitability	No significant need for ramp access, no inline stations	
	Rating: **Moderate**	
Investment Parity		
Overall investment parity	No recent investment; corridor previously identified in 2030 Plan.	
	Rating: **High**	
Opportunity Rating		
Overall opportunity rating	Extensive Bus on Shoulder availability.	
	Rating: **High**	

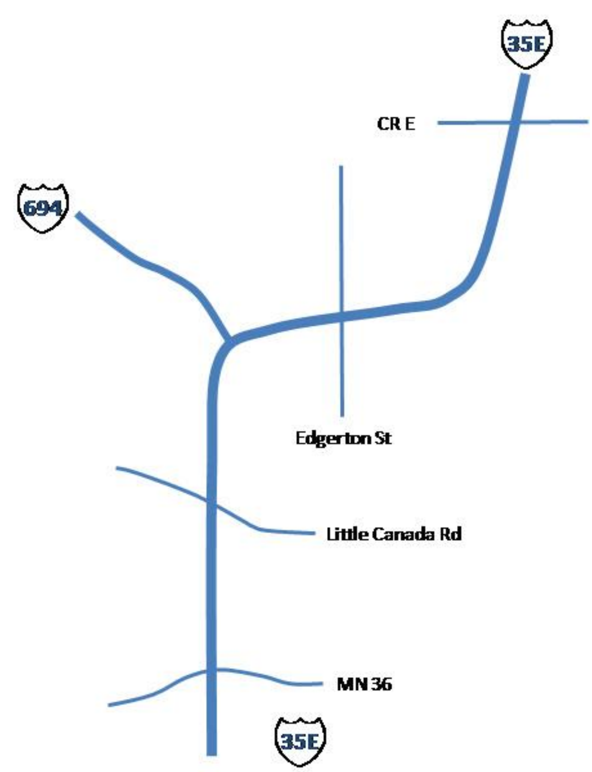
OVERALL CONCLUSION: **High**

Project 4A: I-35E

Type	Conversion
Limits	TH-36 to CR E
Lane Miles	13.58
Cost Estimate	$6,808,000 (low) - $12,025,000 (high)
Cost Risk	.15 (low) - .25 (high)

Managed Lanes Type, Geometric and Other Considerations: Converts left-side general purpose lane to managed lane, maintaining the right-side shoulder. No net increase in laneage. There are no major geometric areas of concern.

Project Metrics	2030
Vehicle Miles of Travel	24,869,713 (build total) - 24,359 (change from no-build)
Vehicle Hours of Travel	813,233 (build total) - 9,733 (change from no-build)
Vehicle Hours of Delay	365,168 (build total) 10,348 (change from no-build)
Vehicular Volumes (change from no-build)	16,430 (total) 1,210 (per lane mile)
Person Trips (change from no build)	19,060 (total) 1,404 (per lane mile)
Peak Vehicle Trips (change from no build)	12,082 (total) 890 (per lane mile)



Project 4A (**I-35E**, *from TH-36 to CR E*)

Measures of Effectiveness	Value	Rank (of 24)
Throughput		
Daily new vehicles per lane mile	1,210 (vehicles)	8
Daily new persons per lane mile	1,404 (persons)	16
	Rating: **Moderate**	
Optimization		
Daily reduction in congested VMT	131,531.0 (miles)	9
Daily peak hours of delay per trip reduced	.43 (minutes)	19
Daily average travel time per trip reduced	1.67 (minutes)	21
	Rating: **Low**	
Reduce SOV Demand		
Change in transit mode sure	.003	13
Change in SOV use rate	- .0375	16
	Rating: **Moderate**	
Cost Effectiveness		
Benefit-cost ratio (mean)	139.57	2
Benefit-cost ratio (standard deviation)	2.48	
	Rating: **High**	
Transit Suitability		
2030 planned transit corridor	Express Bus Corridor	
Existing express bus trips	0 (total AM / PM peak periods)	18
Overall transit suitability	No significant need for ramp access, no inline stations	
	Rating: **Low**	
Investment Parity		
Overall investment parity	Recent investment made in corridor; corridor not identified on 2030 Plan.	
	Rating: **Low**	
Opportunity Rating		
Overall opportunity rating	Existing Bus on Shoulders across much of the corridor	
	Rating: **Moderate**	

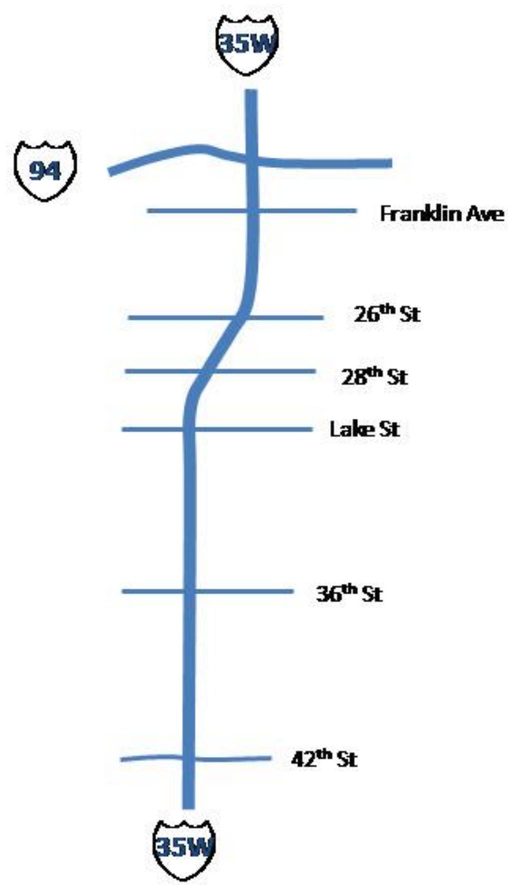
OVERALL CONCLUSION: **Moderate**

Project 6B: I-35W

Type	Asynchronous
Limits	42nd St. to Minneapolis CBD
Lane Miles	3.52
Cost Estimate	$12,938,000 (low) - $18,023,000 (high)
Cost Risk	.25 (low) - .35 (high)

Managed Lanes Type, Geometric and Other Considerations: Managed lane expansion, adding a median based managed lane in southbound direction only. There are no major geometric areas of concern.

Project Metrics	2030
Vehicle Miles of Travel	9,615,525 (build total) - 23,350 (change from no-build)
Vehicle Hours of Travel	338,612 (build total) - 6,237 (change from no-build)
Vehicle Hours of Delay	168,743 (build total) 5,649 (change from no-build)
Vehicular Volumes (change from no-build)	902 (total) 256 (per lane mile)
Person Trips (change from no build)	5,296 (total) 1,504 (per lane mile)
Peak Vehicle Trips (change from no build)	941 (total) 267 (per lane mile)



Project 6B (**I-35W**, *from 42nd St. to Minneapolis CBD*)

Measures of Effectiveness	Value	Rank (of 24)
Throughput		
Daily new vehicles per lane mile	256 (vehicles)	23
Daily new persons per lane mile	1,504 (persons)	14
	Rating: **Low**	
Optimization		
Daily reduction in congested VMT	91,109.0 (miles)	16
Daily peak hours of delay per trip reduced	.74 (minutes)	11
Daily average travel time per trip reduced	2.79 (minutes)	10
	Rating: **Moderate**	
Reduce SOV Demand		
Change in transit mode sure	.003	13
Change in SOV use rate	.0247	8
	Rating: **Moderate**	
Cost Effectiveness		
Benefit-cost ratio (mean)	21.22	8
Benefit-cost ratio (standard deviation)	.38	
	Rating: **Moderate**	
Transit Suitability		
2030 planned transit corridor	Bus Rapid Transit Corridor	
Existing express bus trips	323 (total AM / PM peak periods)	1
Overall transit suitability	No significant need for ramp access; desirable inline stations identified by Metro Transit.	
	Rating: **Very High**	
Investment Parity		
Overall investment parity	No recent investment; corridor previously identified in 2030 Plan.	
	Rating: **High**	
Opportunity Rating		
Overall opportunity rating	Extensive Bus on Shoulder availability.	
	Rating: **High**	

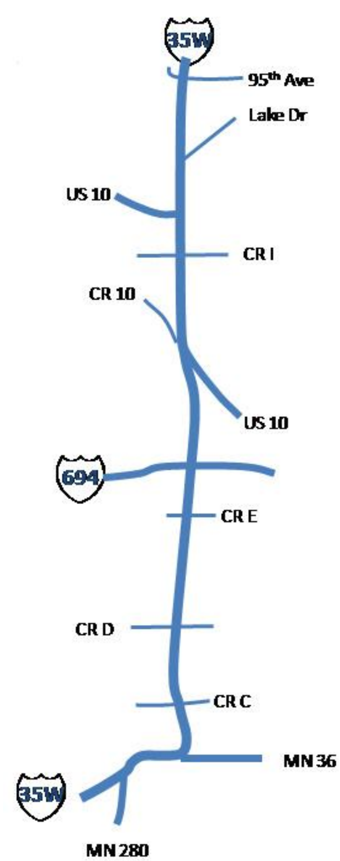
OVERALL CONCLUSION: High

Project 7B: I-35W

Type	Expansion
Limits	TH-280 to 95th Ave
Lane Miles	24.94
Cost Estimate	$143,223,000 (low) - $176,621,000 (high)
Cost Risk	.25 (low) - .35 (high)

Managed Lanes Type, Geometric and Other Considerations: Managed lane expansion, adding a median based managed lane in each direction. Geometric areas of concern are: widen bridge over railroad, widen bridge over CR C, widen bridge over CR I, and southbound left exit to TH-36

Project Metrics	2030
Vehicle Miles of Travel	28,753,217 (build total) 37,780 (change from no-build)
Vehicle Hours of Travel	989,921 (build total) - 21,069 (change from no-build)
Vehicle Hours of Delay	452,735 (build total) 20,922 (change from no-build)
Vehicular Volumes (change from no-build)	17,232 (total) 691 (per lane mile)
Person Trips (change from no build)	35,558 (total) 1,426 (per lane mile)
Peak Vehicle Trips (change from no build)	12,147 (total) 487 (per lane mile)



Project 7B (**I-35W**, *from TH-280 to 95th Ave*)

Measures of Effectiveness	Value	Rank (of 24)
Throughput		
Daily new vehicles per lane mile	691 (vehicles)	15
Daily new persons per lane mile	1,426 (persons)	15
	Rating: **Moderate**	
Optimization		
Daily reduction in congested VMT	233,879.0 (miles)	3
Daily peak hours of delay per trip reduced	.58 (minutes)	15
Daily average travel time per trip reduced	2.4 (minutes)	13
	Rating: **Moderate**	
Reduce SOV Demand		
Change in transit mode sure	.003	13
Change in SOV use rate	- .0301	15
	Rating: **Moderate**	
Cost Effectiveness		
Benefit-cost ratio (mean)	13.64	15
Benefit-cost ratio (standard deviation)	.24	
	Rating: **Moderate**	
Transit Suitability		
2030 planned transit corridor	Bus Rapid Transit Corridor	
Existing express bus trips	76 (total AM / PM peak periods)	9
Overall transit suitability	No significant need for ramp access; desirable inline stations identified by Metro Transit.	
	Rating: **High**	
Investment Parity		
Overall investment parity	No recent investment; corridor was not previously identified in the 2030 Plan.	
	Rating: **Moderate**	
Opportunity Rating		
Overall opportunity rating	Extensive Bus on Shoulder availability.	
	Rating: **High**	

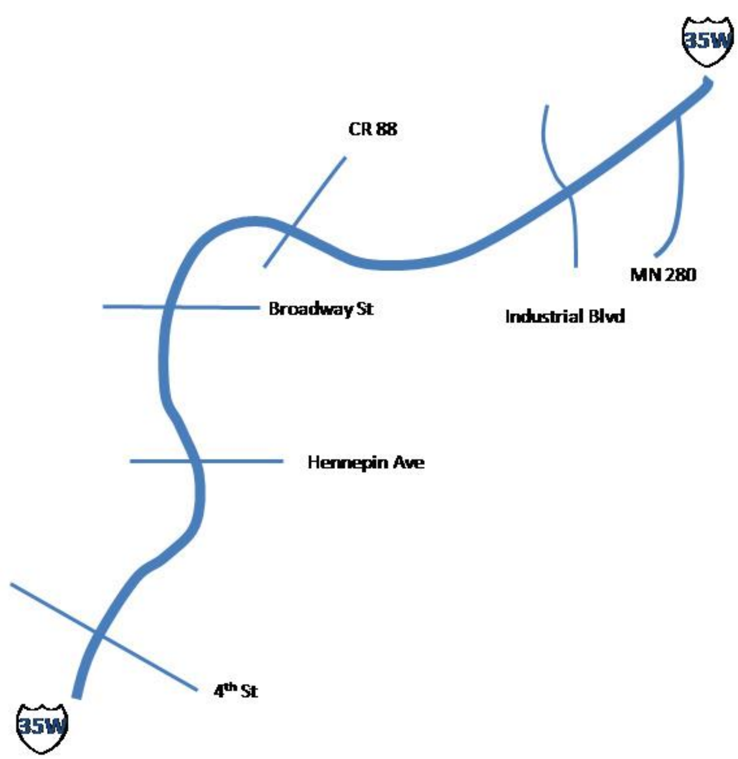
OVERALL CONCLUSION: **High**

Project 10A: I-35W

Type	Expansion
Limits	University to TH-280
Lane Miles	8.04
Cost Estimate	$47,713,000 (low) - $55,715,000 (high)
Cost Risk	.25 (low) - .35 (high)

Managed Lanes Type, Geometric and Other Considerations: Managed lane expansion, adding a median based managed lane in each direction. Geometric areas of concern the bridge over Johnson Street.

Project Metrics	2030
Vehicle Miles of Travel	17,487,030 (build total) 18,905 (change from no-build)
Vehicle Hours of Travel	628,282 (build total) - 9,149 (change from no-build)
Vehicle Hours of Delay	306,913 (build total) 9,232 (change from no-build)
Vehicular Volumes (change from no-build)	12,598 (total) 1,567 (per lane mile)
Person Trips (change from no build)	30,585 (total) 3,804 (per lane mile)
Peak Vehicle Trips (change from no build)	8,885 (total) 1,105 (per lane mile)



Project 10A (**I-35W**, *from University to TH-280*)

Measures of Effectiveness	Value	Rank (of 24)
Throughput		
Daily new vehicles per lane mile	1,567 (vehicles)	5
Daily new persons per lane mile	3,804 (persons)	7
	Rating: **High**	
Optimization		
Daily reduction in congested VMT	91,687.0 (miles)	15
Daily peak hours of delay per trip reduced	.3 (minutes)	20
Daily average travel time per trip reduced	2.21 (minutes)	15
	Rating: **Low**	
Reduce SOV Demand		
Change in transit mode sure	.004	7
Change in SOV use rate	- .0399	17
	Rating: **Moderate**	
Cost Effectiveness		
Benefit-cost ratio (mean)	18.06	11
Benefit-cost ratio (standard deviation)	.32	
	Rating: **Moderate**	
Transit Suitability		
2030 planned transit corridor	Bus Rapid Transit Corridor	
Existing express bus trips	143 (total AM / PM peak periods)	3
Overall transit suitability	Some need for ramp access; no inline stations.	
	Rating: **High**	
Investment Parity		
Overall investment parity	No recent investment; corridor was not previously identified in the 2030 Plan.	
	Rating: **Moderate**	
Opportunity Rating		
Overall opportunity rating	Limited Bus on Shoulders, completion planned.	
	Rating: **Moderate**	

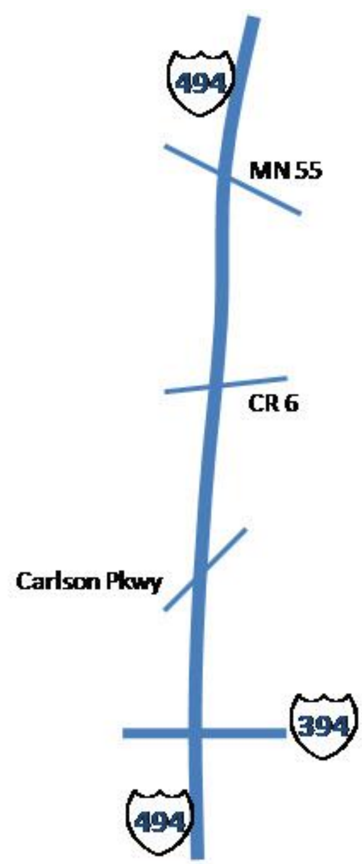
OVERALL CONCLUSION: Moderate

Project 17A: I-494

Type	Conversion
Limits	I-394 to TH-55
Lane Miles	4.80
Cost Estimate	$4,968,000 (low) - $8,775,000 (high)
Cost Risk	.15 (low) - .25 (high)

Managed Lanes Type, Geometric and Other Considerations: Converts left-side general purpose lane to managed lane, maintaining the right-side shoulder. No net increase in laneage. There are no major geometric areas of concern.

Project Metrics	2030
Vehicle Miles of Travel	19,094,389 (build total) - 55,287 (change from no-build)
Vehicle Hours of Travel	679,009 (build total) - 14,466 (change from no-build)
Vehicle Hours of Delay	343,750 (build total) 13,326 (change from no-build)
Vehicular Volumes (change from no-build)	581 (total) 121 (per lane mile)
Person Trips (change from no build)	9,607 (total) 2,001 (per lane mile)
Peak Vehicle Trips (change from no build)	255 (total) 53 (per lane mile)



Project 17A (**I-494**, *from I-394 to TH-55*)

Measures of Effectiveness	Value	Rank (of 24)
Throughput		
Daily new vehicles per lane mile	121 (vehicles)	24
Daily new persons per lane mile	2,001 (persons)	11
	Rating: **Low**	
Optimization		
Daily reduction in congested VMT	101,438.0 (miles)	13
Daily peak hours of delay per trip reduced	.5 (minutes)	17
Daily average travel time per trip reduced	6.68 (minutes)	2
	Rating: **Moderate**	
Reduce SOV Demand		
Change in transit mode sure	.004	7
Change in SOV use rate	.0792	3
	Rating: **High**	
Cost Effectiveness		
Benefit-cost ratio (mean)	255.06	1
Benefit-cost ratio (standard deviation)	4.53	
	Rating: **High**	
Transit Suitability		
2030 planned transit corridor	Not a transit corridor	
Existing express bus trips	0 (total AM / PM peak periods)	18
Overall transit suitability	No significant need for ramp access, no inline stations	
	Rating: **Very Low**	
Investment Parity		
Overall investment parity	No recent investment; corridor previously identified in 2030 Plan.	
	Rating: **High**	
Opportunity Rating		
Overall opportunity rating	No existing Bus on Shoulder availability; no Bus on Shoulders are planned	
	Rating: **Low**	

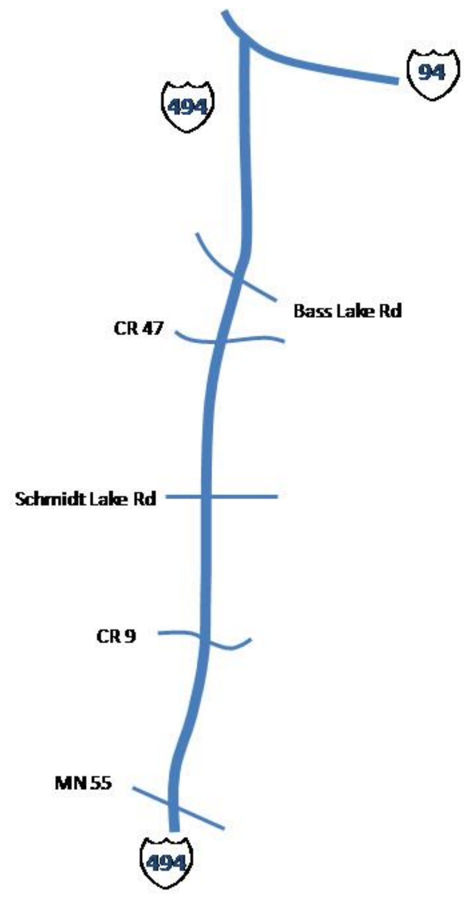
OVERALL CONCLUSION: Moderate

Project 18A: I-494

Type	Expansion
Limits	TH-55 to I-94 /I-494
Lane Miles	16.24
Cost Estimate	$75,728,400 (low) - $107,163,000 (high)
Cost Risk	.25 (low) - .35 (high)

Managed Lanes Type, Geometric and Other Considerations: Managed lane expansion, adding a median based managed lane in each direction. Geometric areas of concern are: widen bridge over Schmidt Lake Road, widen bridge over railroad, and widen bridge over CR 47.

Project Metrics	2030
Vehicle Miles of Travel	22,528,332 (build total) 61,038 (change from no-build)
Vehicle Hours of Travel	809,286 (build total) - 12,252 (change from no-build)
Vehicle Hours of Delay	406,276 (build total) 12,998 (change from no-build)
Vehicular Volumes (change from no-build)	12,680 (total) 781 (per lane mile)
Person Trips (change from no build)	32,471 (total) 1,999 (per lane mile)
Peak Vehicle Trips (change from no build)	9,995 (total) 615 (per lane mile)



Project 18A (**I-494**, *from TH-55 to I-94 /I-494*)

Measures of Effectiveness	Value	Rank (of 24)
Throughput		
Daily new vehicles per lane mile	781 (vehicles)	13
Daily new persons per lane mile	1,999 (persons)	12
	Rating: **Moderate**	
Optimization		
Daily reduction in congested VMT	96,685.0 (miles)	14
Daily peak hours of delay per trip reduced	.55 (minutes)	16
Daily average travel time per trip reduced	3.63 (minutes)	7
	Rating: **Moderate**	
Reduce SOV Demand		
Change in transit mode sure	.007	1
Change in SOV use rate	.0393	7
	Rating: **High**	
Cost Effectiveness		
Benefit-cost ratio (mean)	14.43	14
Benefit-cost ratio (standard deviation)	.26	
	Rating: **Moderate**	
Transit Suitability		
2030 planned transit corridor	Not a transit corridor	
Existing express bus trips	0 (total AM / PM peak periods)	18
Overall transit suitability	No significant need for ramp access, no inline stations	
	Rating: **Very Low**	
Investment Parity		
Overall investment parity	No recent investment; corridor previously identified in 2030 Plan.	
	Rating: **High**	
Opportunity Rating		
Overall opportunity rating	No existing Bus on Shoulder availability; no Bus on Shoulders are planned	
	Rating: **Low**	

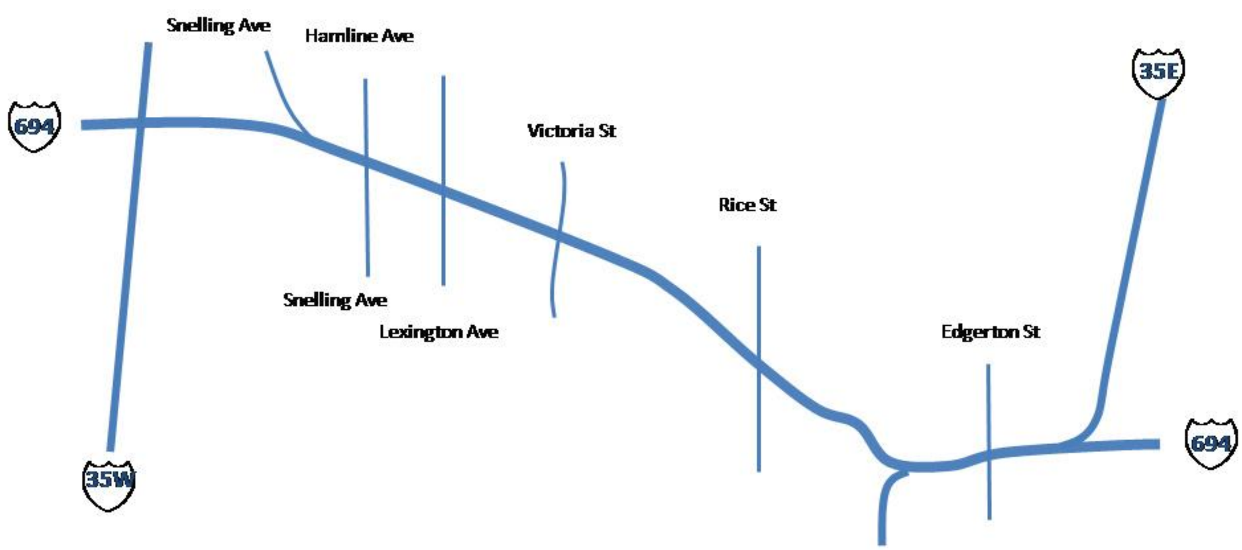
OVERALL CONCLUSION: **Moderate**

Project 19A: I-694

Type	Expansion
Limits	I-35W to I-35E
Lane Miles	10.30
Cost Estimate	$36,553,000 (low) - $47,250,000 (high)
Cost Risk	.25 (low) - .35 (high)

Managed Lanes Type, Geometric and Other Considerations: Managed lane expansion, adding a median based managed lane in each direction. Geometric areas of concern are: reconstruction of I-694/US 10/Snelling Interchange, widen bridge over Island Lake, and the underpass railroad bridge replacement.

Project Metrics	2030
Vehicle Miles of Travel	22,450,827 (build total) 64,715 (change from no-build)
Vehicle Hours of Travel	711,953 (build total) - 5,171 (change from no-build)
Vehicle Hours of Delay	311,287 (build total) 6,814 (change from no-build)
Vehicular Volumes (change from no-build)	19,522 (total) 1,895 (per lane mile)
Person Trips (change from no build)	39,688 (total) 3,853 (per lane mile)
Peak Vehicle Trips (change from no build)	15,156 (total) 1,471 (per lane mile)



Project 19A (**I-694**, *from I-35W to I-35E*)

Measures of Effectiveness	Value	Rank (of 24)
Throughput		
Daily new vehicles per lane mile	1,895 (vehicles)	3
Daily new persons per lane mile	3,853 (persons)	6
	Rating: **High**	
Optimization		
Daily reduction in congested VMT	8,615.0 (miles)	24
Daily peak hours of delay per trip reduced	.97 (minutes)	5
Daily average travel time per trip reduced	1.56 (minutes)	23
	Rating: **Low**	
Reduce SOV Demand		
Change in transit mode sure	.006	3
Change in SOV use rate	.0112	9
	Rating: **High**	
Cost Effectiveness		
Benefit-cost ratio (mean)	16.4	13
Benefit-cost ratio (standard deviation)	.29	
	Rating: **Moderate**	
Transit Suitability		
2030 planned transit corridor	Not a transit corridor	
Existing express bus trips	6 (total AM / PM peak periods)	17
Overall transit suitability	No significant need for ramp access, no inline stations	
	Rating: **Low**	
Investment Parity		
Overall investment parity	No recent investment; corridor previously identified in 2030 Plan.	
	Rating: **High**	
Opportunity Rating		
Overall opportunity rating	Extensive Bus on Shoulder availability.	
	Rating: **High**	

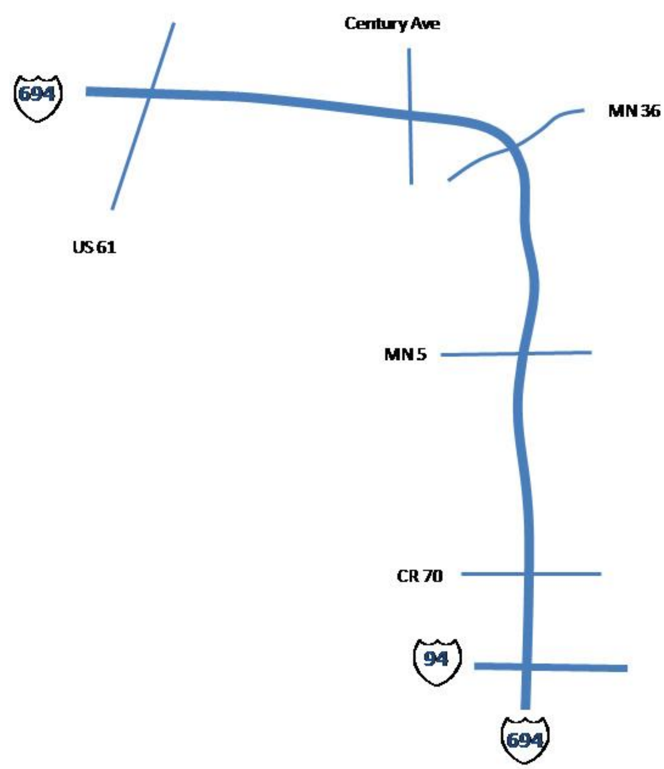
OVERALL CONCLUSION: **High**

Project 20B: I-694

Type	Expansion
Limits	I-94 to US 61
Lane Miles	20.64
Cost Estimate	$75,265,000 (low) - $117,180,000 (high)
Cost Risk	.25 (low) - .35 (high)

Managed Lanes Type, Geometric and Other Considerations: Managed lane expansion, adding a median based managed lane in each direction. Geometric areas of concern are: widen bridge over railroad, widen bridge over TH-5, widen bridge over 50th Street N, widen bridge at Willard Mungar Trail, widen bridge over TH-36, widen bridge over White Bear Ave, underpass railroad bridge replacement, and widen bridge over US 61.

Project Metrics	2030
Vehicle Miles of Travel	24,269,578 (build total) 65,230 (change from no-build)
Vehicle Hours of Travel	775,497 (build total) - 9,445 (change from no-build)
Vehicle Hours of Delay	339,573 (build total) 10,020 (change from no-build)
Vehicular Volumes (change from no-build)	16,715 (total) 810 (per lane mile)
Person Trips (change from no build)	14,981 (total) 726 (per lane mile)
Peak Vehicle Trips (change from no build)	12,659 (total) 613 (per lane mile)



Project 20B (**I-694**, *from I-94 to US 61*)

Measures of Effectiveness	Value	Rank (of 24)
Throughput		
Daily new vehicles per lane mile	810 (vehicles)	12
Daily new persons per lane mile	726 (persons)	22
	Rating: **Moderate**	
Optimization		
Daily reduction in congested VMT	212,827.0 (miles)	5
Daily peak hours of delay per trip reduced	.65 (minutes)	14
Daily average travel time per trip reduced	2.47 (minutes)	12
	Rating: **Moderate**	
Reduce SOV Demand		
Change in transit mode sure	.002	18
Change in SOV use rate	.0043	10
	Rating: **Moderate**	
Cost Effectiveness		
Benefit-cost ratio (mean)	12.44	16
Benefit-cost ratio (standard deviation)	.22	
	Rating: **Low**	
Transit Suitability		
2030 planned transit corridor	Not a transit corridor	
Existing express bus trips	0 (total AM / PM peak periods)	18
Overall transit suitability	No significant need for ramp access, no inline stations	
	Rating: **Very Low**	
Investment Parity		
Overall investment parity	No recent investment; corridor previously identified in 2030 Plan.	
	Rating: **High**	
Opportunity Rating		
Overall opportunity rating	No existing Bus on Shoulder availability; no Bus on Shoulders are planned	
	Rating: **Low**	

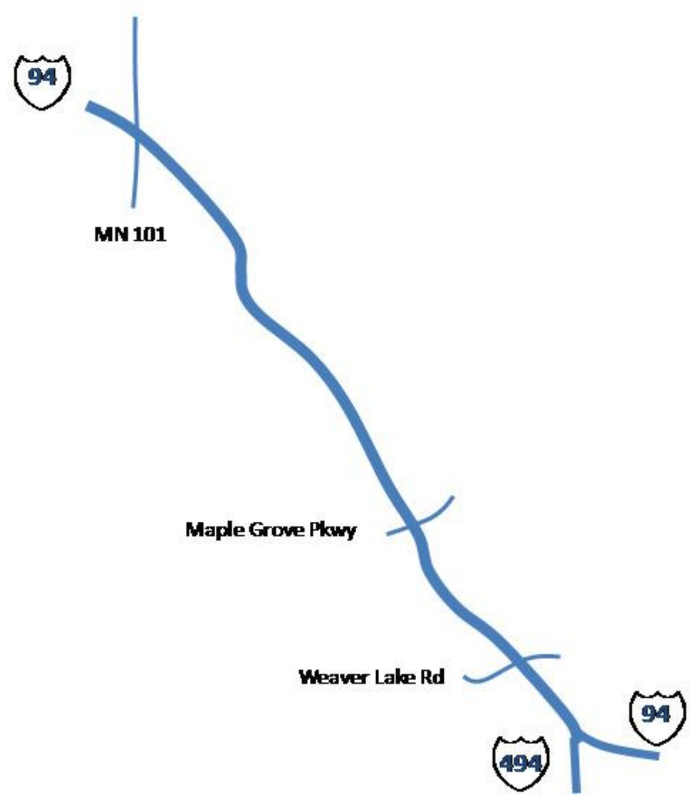
OVERALL CONCLUSION: Low

Project 21B: I-94

Type	Expansion
Limits	TH-101 to I-94 /I-494
Lane Miles	34.32
Cost Estimate	$115,025,000 (low) - $135,837,000 (high)
Cost Risk	.25 (low) - .35 (high)

Managed Lanes Type, Geometric and Other Considerations: Managed lane expansion, adding a median based managed lane in each direction. Geometric areas of concern are a design exception needed for EB lanes under TH-101

Project Metrics	2030
Vehicle Miles of Travel	26,404,400 (build total) - 44,732 (change from no-build)
Vehicle Hours of Travel	878,139 (build total) - 22,989 (change from no-build)
Vehicle Hours of Delay	408,570 (build total) 21,662 (change from no-build)
Vehicular Volumes (change from no-build)	10,433 (total) 304 (per lane mile)
Person Trips (change from no build)	27,485 (total) 801 (per lane mile)
Peak Vehicle Trips (change from no build)	8,158 (total) 238 (per lane mile)



Project 21B (**I-94**, *from TH-101 to I-94 /I-494*)

Measures of Effectiveness	Value	Rank (of 24)
Throughput		
Daily new vehicles per lane mile	304 (vehicles)	22
Daily new persons per lane mile	801 (persons)	19
	Rating: **Low**	
Optimization		
Daily reduction in congested VMT	277,055.0 (miles)	2
Daily peak hours of delay per trip reduced	1.51 (minutes)	2
Daily average travel time per trip reduced	4.31 (minutes)	5
	Rating: **High**	
Reduce SOV Demand		
Change in transit mode sure	.005	4
Change in SOV use rate	.0758	4
	Rating: **High**	
Cost Effectiveness		
Benefit-cost ratio (mean)	17.73	12
Benefit-cost ratio (standard deviation)	.31	
	Rating: **Moderate**	
Transit Suitability		
2030 planned transit corridor	Express Bus Corridor	
Existing express bus trips	22 (total AM / PM peak periods)	15
Overall transit suitability	No significant need for ramp access, no inline stations	
	Rating: **Moderate**	
Investment Parity		
Overall investment parity	No recent investment; corridor was not previously identified in the 2030 Plan.	
	Rating: **Moderate**	
Opportunity Rating		
Overall opportunity rating	Limited Bus on Shoulders, completion planned.	
	Rating: **Moderate**	

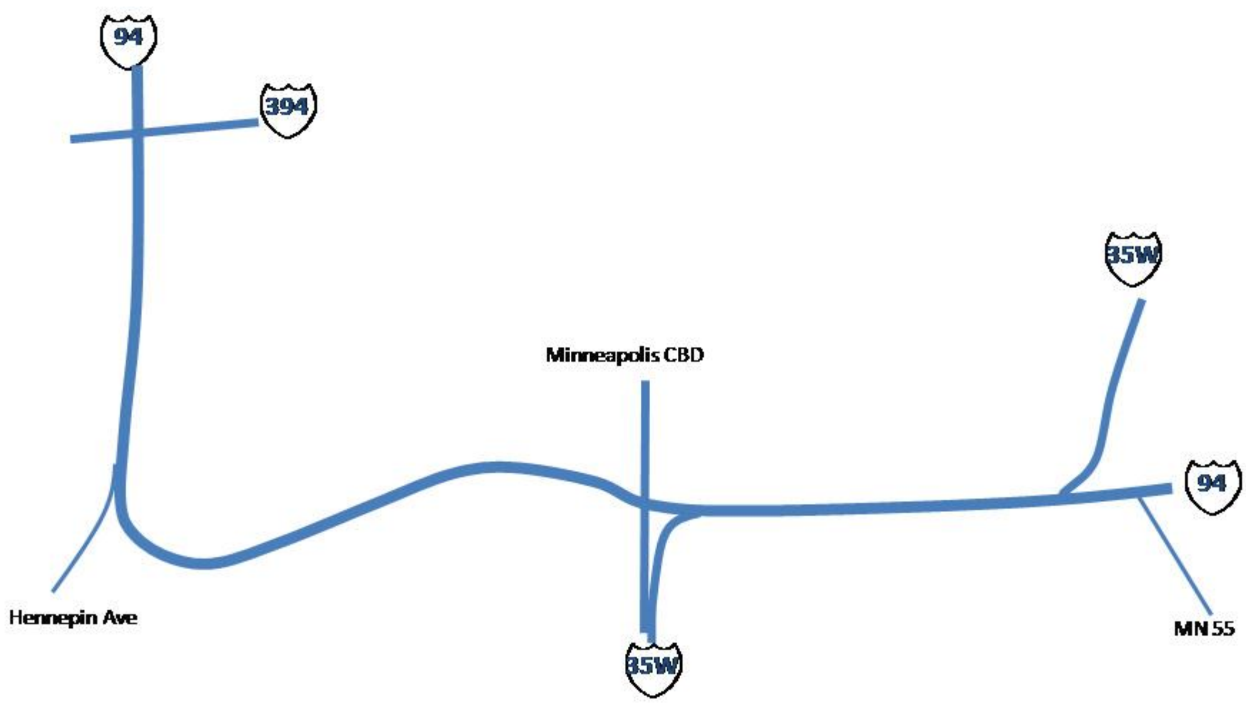
OVERALL CONCLUSION: **Moderate**

Project 22B: I-94

Type	Asynchronous
Limits	Hiawatha to I-394
Lane Miles	1.92
Cost Estimate	$9,919,000 (low) - $13,817,000 (high)
Cost Risk	.25 (low) - .35 (high)

Managed Lanes Type, Geometric and Other Considerations: Managed lane expansion, adding a median based managed lane in westbound direction only. Geometric areas of concern are: connectivity concerns and spacing at the Lowry Hill Tunnel.

Project Metrics	2030
Vehicle Miles of Travel	9,034,482 (build total) - 35,468 (change from no-build)
Vehicle Hours of Travel	324,458 (build total) - 5,394 (change from no-build)
Vehicle Hours of Delay	157,767 (build total) 4,843 (change from no-build)
Vehicular Volumes (change from no-build)	1,766 (total) 920 (per lane mile)
Person Trips (change from no build)	- 1,475 (total) - 768 (per lane mile)
Peak Vehicle Trips (change from no build)	1,681 (total) 876 (per lane mile)



Project 22B (**I-94**, *from Hiawatha to I-394*)

Measures of Effectiveness	Value	Rank (of 24)
Throughput		
Daily new vehicles per lane mile	920 (vehicles)	11
Daily new persons per lane mile	- 768 (persons)	24
	Rating: **Low**	
Optimization		
Daily reduction in congested VMT	36,460.0 (miles)	19
Daily peak hours of delay per trip reduced	.19 (minutes)	21
Daily average travel time per trip reduced	3.11 (minutes)	9
	Rating: **Low**	
Reduce SOV Demand		
Change in transit mode sure	.001	21
Change in SOV use rate	.159	1
	Rating: **Moderate**	
Cost Effectiveness		
Benefit-cost ratio (mean)	37.97	6
Benefit-cost ratio (standard deviation)	.67	
	Rating: **High**	
Transit Suitability		
2030 planned transit corridor	Bus Rapid Transit Corridor	
Existing express bus trips	304 (total AM / PM peak periods)	2
Overall transit suitability	Significant bus volumes entering from ramps; access on right side of managed capacity may be necesssary to accommodate entering buses	
	Rating: **High**	
Investment Parity		
Overall investment parity	No recent investment; corridor was not previously identified in the 2030 Plan.	
	Rating: **Moderate**	
Opportunity Rating		
Overall opportunity rating	Extensive Bus on Shoulder availability.	
	Rating: **High**	

OVERALL CONCLUSION: Moderate

Project 23A: I-94

Type	Expansion
Limits	Cedar to Marion
Lane Miles	14.24
Cost Estimate	$110,413,000 (low) - $150,647,000 (high)
Cost Risk	.25 (low) - .35 (high)

Managed Lanes Type, Geometric and Other Considerations: Managed lane expansion, adding a median based managed lane in each direction. Geometric areas of concern are: ramp modifications at Cretin/Vandilia, Pascal Street, Marion/Kellogg, and 5th/10th Street.

Project Metrics	2030
Vehicle Miles of Travel	21,411,148 (build total) - 18,240 (change from no-build)
Vehicle Hours of Travel	699,749 (build total) - 12,385 (change from no-build)
Vehicle Hours of Delay	302,519 (build total) 11,845 (change from no-build)
Vehicular Volumes (change from no-build)	23,838 (total) 1,674 (per lane mile)
Person Trips (change from no build)	33,472 (total) 2,351 (per lane mile)
Peak Vehicle Trips (change from no build)	14,810 (total) 1,040 (per lane mile)

Measures of Effectiveness	Value	Rank (of 24)
Throughput		
Daily new vehicles per lane mile	1,674 (vehicles)	4
Daily new persons per lane mile	2,351 (persons)	10
	Rating: **High**	
Optimization		
Daily reduction in congested VMT	110,646.0 (miles)	11
Daily peak hours of delay per trip reduced	.09 (minutes)	24
Daily average travel time per trip reduced	1.99 (minutes)	18
	Rating: **Low**	
Reduce SOV Demand		
Change in transit mode sure	.004	7
Change in SOV use rate	- .0561	18
	Rating: **Moderate**	
Cost Effectiveness		
Benefit-cost ratio (mean)	9.57	21
Benefit-cost ratio (standard deviation)	.17	
	Rating: **Low**	
Transit Suitability		
2030 planned transit corridor	Bus Rapid Transit Corridor	
Existing express bus trips	142 (total AM / PM peak periods)	4
Overall transit suitability	Significant bus volumes on ramps may require additional accommodation with inline station location.	
	Rating: **High**	
Investment Parity		
Overall investment parity	No recent investment; corridor was not previously identified in the 2030 Plan.	
	Rating: **Moderate**	
Opportunity Rating		
Overall opportunity rating	Extensive Bus on Shoulder availability.	
	Rating: **High**	

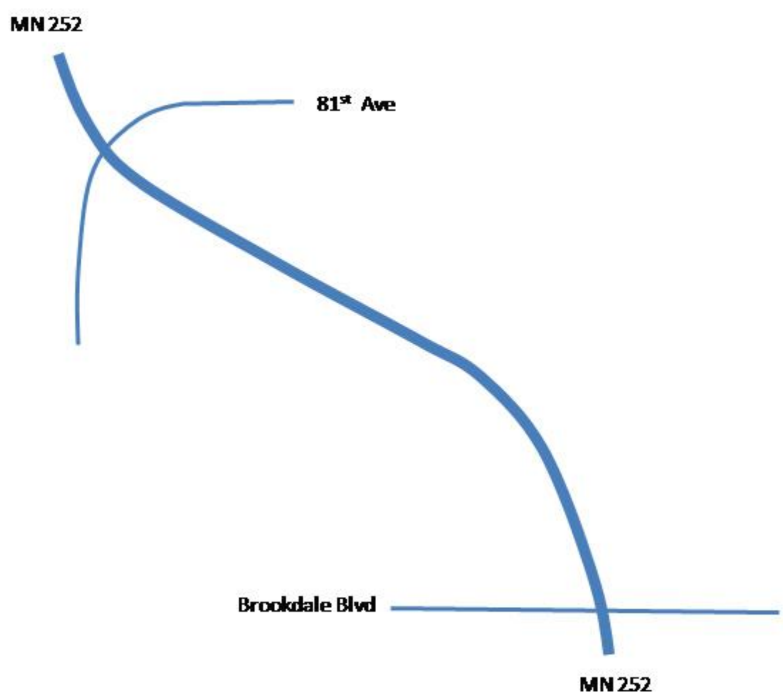
OVERALL CONCLUSION: Moderate

Project 26B: TH-252

Type	Asynchronous
Limits	77th Ave to 81st Ave
Lane Miles	.66
Cost Estimate	$2,363,000 (low) - $3,497,000 (high)
Cost Risk	.25 (low) - .35 (high)

Managed Lanes Type, Geometric and Other Considerations: Managed lane expansion, adding a median based managed lane in northbound direction only. Geometric areas of concern are: intersection modifications at Brookdale Drive and 81st Avenue.

Project Metrics	2030
Vehicle Miles of Travel	5,111,857 (build total) - 23,545 (change from no-build)
Vehicle Hours of Travel	221,104 (build total) - 3,965 (change from no-build)
Vehicle Hours of Delay	119,598 (build total) 3,472 (change from no-build)
Vehicular Volumes (change from no-build)	271 (total) 410 (per lane mile)
Person Trips (change from no build)	1,873 (total) 2,838 (per lane mile)
Peak Vehicle Trips (change from no build)	148 (total) 225 (per lane mile)



Project 26B (**TH-252**, *from 77th Ave to 81st Ave*)

Measures of Effectiveness	Value	Rank (of 24)
Throughput		
Daily new vehicles per lane mile	410 (vehicles)	19
Daily new persons per lane mile	2,838 (persons)	8
	Rating: **Moderate**	
Optimization		
Daily reduction in congested VMT	26,099.0 (miles)	22
Daily peak hours of delay per trip reduced	.95 (minutes)	6
Daily average travel time per trip reduced	12.95 (minutes)	1
	Rating: **Moderate**	
Reduce SOV Demand		
Change in transit mode sure	.004	7
Change in SOV use rate	.0538	5
	Rating: **High**	
Cost Effectiveness		
Benefit-cost ratio (mean)	108.53	3
Benefit-cost ratio (standard deviation)	1.93	
	Rating: **High**	
Transit Suitability		
2030 planned transit corridor	Express Bus Corridor	
Existing express bus trips	140 (total AM / PM peak periods)	5
Overall transit suitability	No significant bus access to ramps; multiple desirable inline stations by MetroTransit along the corridor (but not in the vicinity of the project)	
	Rating: **Very High**	
Investment Parity		
Overall investment parity	Recent investment in the corridor; corridor was previously identified in the 2030 Plan.	
	Rating: **Moderate**	
Opportunity Rating		
Overall opportunity rating	Extensive Bus on Shoulder availability.	
	Rating: **High**	

OVERALL CONCLUSION: High

Project 27A: TH-36

Type	Expansion
Limits	I-35W to I-35E
Lane Miles	17.28
Cost Estimate	$39,031,000 (low) - $56,166,000 (high)
Cost Risk	.15 (low) - .25 (high)

Managed Lanes Type, Geometric and Other Considerations: Managed lane expansion, adding a median based managed lane in each direction. Geometric areas of concern are: widen WB bridge over Cleveland, widen EB and WB bridges over Fairview, widen bridge over Lexington Ave, and the I-35E underpass requires design exception.

Project Metrics	2030
Vehicle Miles of Travel	23,573,886 (build total) 3,173 (change from no-build)
Vehicle Hours of Travel	839,382 (build total) - 16,575 (change from no-build)
Vehicle Hours of Delay	397,072 (build total) 16,096 (change from no-build)
Vehicular Volumes (change from no-build)	9,893 (total) 573 (per lane mile)
Person Trips (change from no build)	26,080 (total) 1,509 (per lane mile)
Peak Vehicle Trips (change from no build)	7,202 (total) 417 (per lane mile)

Measures of Effectiveness	Value	Rank (of 24)
Throughput		
Daily new vehicles per lane mile	573 (vehicles)	17
Daily new persons per lane mile	1,509 (persons)	13
	Rating: **Moderate**	
Optimization		
Daily reduction in congested VMT	224,568.0 (miles)	4
Daily peak hours of delay per trip reduced	.69 (minutes)	12
Daily average travel time per trip reduced	2.16 (minutes)	16
	Rating: **Moderate**	
Reduce SOV Demand		
Change in transit mode sure	.003	13
Change in SOV use rate	- .0566	19
	Rating: **Moderate**	
Cost Effectiveness		
Benefit-cost ratio (mean)	38.45	5
Benefit-cost ratio (standard deviation)	.68	
	Rating: **High**	
Transit Suitability		
2030 planned transit corridor	Bus Rapid Transit Corridor	
Existing express bus trips	41 (total AM / PM peak periods)	12
Overall transit suitability	No significant need for ramp access; one desirable inline station location.	
	Rating: **High**	
Investment Parity		
Overall investment parity	No recent investment; corridor previously identified in 2030 Plan.	
	Rating: **High**	
Opportunity Rating		
Overall opportunity rating	Extensive Bus on Shoulder availability.	
	Rating: **High**	

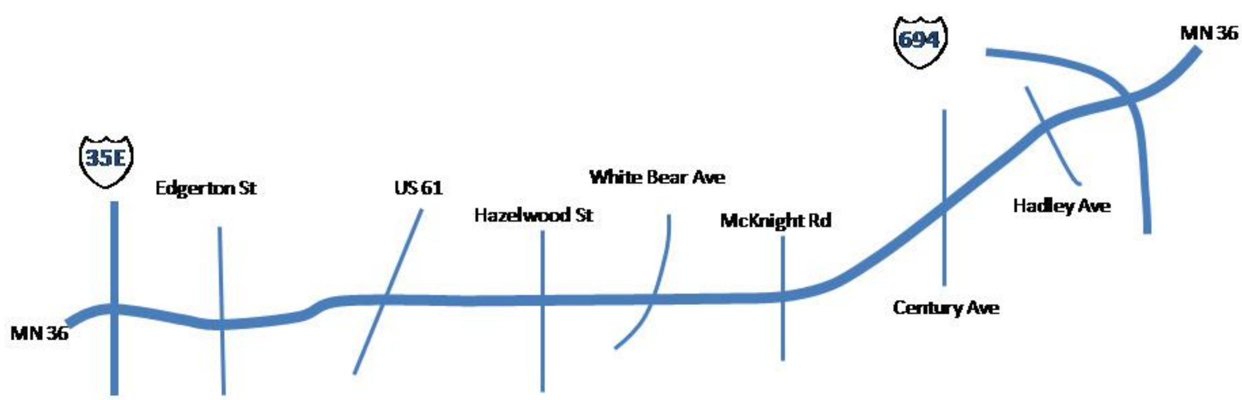
OVERALL CONCLUSION: High

Project 28B: TH-36

Type	Expansion
Limits	I-35E to I-694
Lane Miles	32.16
Cost Estimate	$50,416,000 (low) - $71,070,000 (high)
Cost Risk	.15 (low) - .25 (high)

Managed Lanes Type, Geometric and Other Considerations: Managed lane expansion, adding a median based managed lane in each direction. Geometric areas of concern are: widen Keller Lake Bridge, widen bridge at TH-61, widen bridge at White Bear Ave, widen bridge at McKnight Road, intersection modification at Century Avenue, intersection modification at Hadley Avenue and replacement of railroad bridge at Bruce Vento Trail.

Project Metrics	2030
Vehicle Miles of Travel	29,346,119 (build total) - 14,889 (change from no-build)
Vehicle Hours of Travel	1,006,489 (build total) - 24,916 (change from no-build)
Vehicle Hours of Delay	458,993 (build total) 23,881 (change from no-build)
Vehicular Volumes (change from no-build)	10,287 (total) 320 (per lane mile)
Person Trips (change from no build)	25,665 (total) 798 (per lane mile)
Peak Vehicle Trips (change from no build)	6,982 (total) 217 (per lane mile)



Project 28B (**TH-36**, *from I-35E to I-694*)

Measures of Effectiveness	Value	Rank (of 24)
Throughput		
Daily new vehicles per lane mile	320 (vehicles)	21
Daily new persons per lane mile	798 (persons)	20
	Rating: **Low**	
Optimization		
Daily reduction in congested VMT	302,410.0 (miles)	1
Daily peak hours of delay per trip reduced	.77 (minutes)	10
Daily average travel time per trip reduced	2.58 (minutes)	11
	Rating: **Moderate**	
Reduce SOV Demand		
Change in transit mode sure	.004	7
Change in SOV use rate	- .0017	11
	Rating: **Moderate**	
Cost Effectiveness		
Benefit-cost ratio (mean)	43.08	4
Benefit-cost ratio (standard deviation)	.76	
	Rating: **High**	
Transit Suitability		
2030 planned transit corridor	Bus Rapid Transit Corridor	
Existing express bus trips	53 (total AM / PM peak periods)	11
Overall transit suitability	Some need for ramp access; may require inline station consideration, despite one not identiifed.	
	Rating: **High**	
Investment Parity		
Overall investment parity	Recent investment made in corridor; corridor not identified on 2030 Plan.	
	Rating: **Low**	
Opportunity Rating		
Overall opportunity rating	Extensive Bus on Shoulder availability.	
	Rating: **High**	

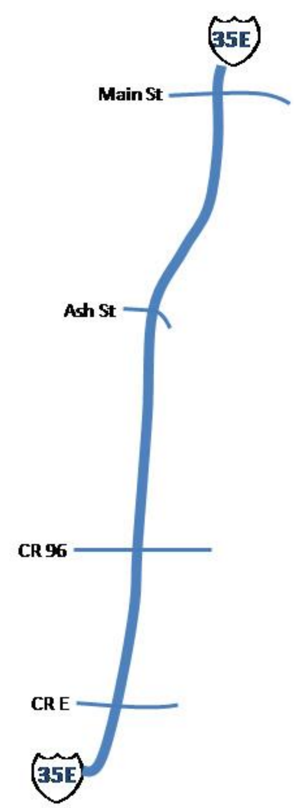
OVERALL CONCLUSION: **Moderate**

Project 29B: I-35E

Type	Expansion
Limits	CR E to CSAH 14
Lane Miles	29.98
Cost Estimate	$103,811,000 (low) - $137,388,000 (high)
Cost Risk	.15 (low) - .25 (high)

Managed Lanes Type, Geometric and Other Considerations: Managed lane expansion, adding a median based managed lane in each direction. Geometric areas of concern area: widen bridge over Goose Lake Road, a design exception for bridges under TH-96, railroad, CR H2, and Ash Street.

Project Metrics	2030
Vehicle Miles of Travel	25,658,044 (build total) 24,178 (change from no-build)
Vehicle Hours of Travel	838,311 (build total) - 13,307 (change from no-build)
Vehicle Hours of Delay	372,008 (build total) 14,020 (change from no-build)
Vehicular Volumes (change from no-build)	21,854 (total) 729 (per lane mile)
Person Trips (change from no build)	37,327 (total) 1,245 (per lane mile)
Peak Vehicle Trips (change from no build)	14,944 (total) 498 (per lane mile)



Project 29B (**I-35E**, *from CR E to CSAH 14*)

Measures of Effectiveness	Value	Rank (of 24)
Throughput		
Daily new vehicles per lane mile	729 (vehicles)	14
Daily new persons per lane mile	1,245 (persons)	17
	Rating: **Moderate**	
Optimization		
Daily reduction in congested VMT	106,631.0 (miles)	12
Daily peak hours of delay per trip reduced	.46 (minutes)	18
Daily average travel time per trip reduced	2.04 (minutes)	17
	Rating: **Low**	
Reduce SOV Demand		
Change in transit mode sure	.003	13
Change in SOV use rate	- .0181	14
	Rating: **Moderate**	
Cost Effectiveness		
Benefit-cost ratio (mean)	12.16	17
Benefit-cost ratio (standard deviation)	.22	
	Rating: **Moderate**	
Transit Suitability		
2030 planned transit corridor	Express Bus Corridor	
Existing express bus trips	0 (total AM / PM peak periods)	18
Overall transit suitability	No significant need for ramp access, no inline stations	
	Rating: **Low**	
Investment Parity		
Overall investment parity	No recent investment; corridor was not previously identified in the 2030 Plan.	
	Rating: **Moderate**	
Opportunity Rating		
Overall opportunity rating	No current Bus on Shoulders, completion planned.	
	Rating: **Moderate**	

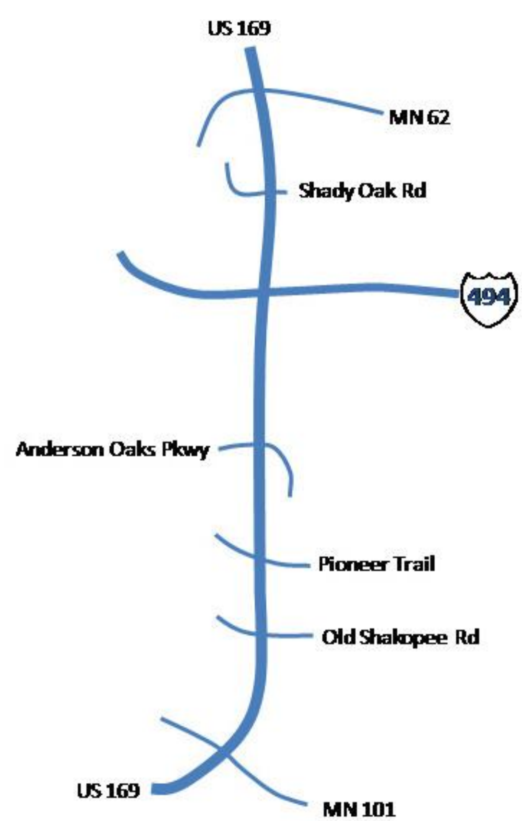
OVERALL CONCLUSION: Low

Project 41A: US 169

Type	Expansion
Limits	Minnesota River to TH-62
Lane Miles	9.52
Cost Estimate	$92,625,000 (low) - $115,587,000 (high)
Cost Risk	.25 (low) - .35 (high)

Managed Lanes Type, Geometric and Other Considerations: Managed lane expansion, adding a median based managed lane in each direction. Geometric areas of concern are: widen bridges over Anderson Lakes, and widen bridge over TH-62/ TH-212.

Project Metrics	2030
Vehicle Miles of Travel	14,775,104 (build total) 47,790 (change from no-build)
Vehicle Hours of Travel	478,644 (build total) - 7,584 (change from no-build)
Vehicle Hours of Delay	207,815 (build total) 7,938 (change from no-build)
Vehicular Volumes (change from no-build)	13,979 (total) 1,468 (per lane mile)
Person Trips (change from no build)	56,555 (total) 5,941 (per lane mile)
Peak Vehicle Trips (change from no build)	8,334 (total) 875 (per lane mile)



Project 41A (**US 169**, *from Minnesota River to TH-62*)

Measures of Effectiveness	Value	Rank (of 24)
Throughput		
Daily new vehicles per lane mile	1,468 (vehicles)	6
Daily new persons per lane mile	5,941 (persons)	3
	Rating: **High**	
Optimization		
Daily reduction in congested VMT	22,035.0 (miles)	23
Daily peak hours of delay per trip reduced	3.38 (minutes)	1
Daily average travel time per trip reduced	3.2 (minutes)	8
	Rating: **Moderate**	
Reduce SOV Demand		
Change in transit mode sure	.007	1
Change in SOV use rate	- .0123	13
	Rating: **Moderate**	
Cost Effectiveness		
Benefit-cost ratio (mean)	7.62	23
Benefit-cost ratio (standard deviation)	.14	
	Rating: **Low**	
Transit Suitability		
2030 planned transit corridor	Express Bus Corridor	
Existing express bus trips	21 (total AM / PM peak periods)	16
Overall transit suitability	No significant need for ramp access, no inline stations	
	Rating: **Moderate**	
Investment Parity		
Overall investment parity	No recent investment; corridor previously identified in 2030 Plan.	
	Rating: **High**	
Opportunity Rating		
Overall opportunity rating	Extensive Bus on Shoulder availability.	
	Rating: **High**	

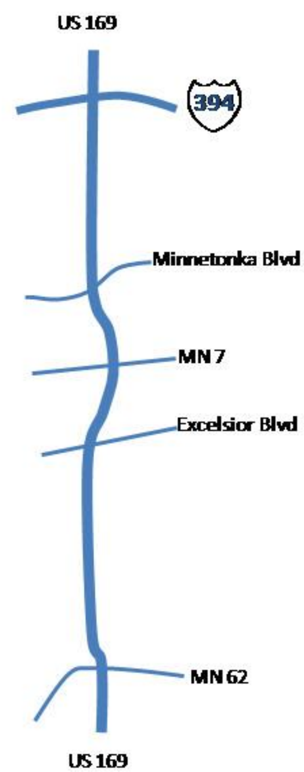
OVERALL CONCLUSION: **Moderate**

Project 42B: US 169

Type	Expansion
Limits	TH-62 to I-394
Lane Miles	15.46
Cost Estimate	$140,965,000 (low) - $238,712,000 (high)
Cost Risk	.25 (low) - .35 (high)

Managed Lanes Type, Geometric and Other Considerations: Managed lane expansion, adding a median based managed lane in each direction. Geometric areas of concern are: widen bridges over TH-62/TH-212, widen bridge over Nine-Mile Creek, widen bridge over Excelsior Blvd, widen bridge over Minnetonka Mills, widen bridge over Minnehaha Creek, widen bridge over railroad, widen bridge over I-394 Frontage Road, replace bridge at Minnetonka Bouelvard, and replace bridge at Cedar Lake Road.

Project Metrics	2030
Vehicle Miles of Travel	22,973,869 (build total) - 5,686 (change from no-build)
Vehicle Hours of Travel	856,709 (build total) - 16,424 (change from no-build)
Vehicle Hours of Delay	434,498 (build total) 16,127 (change from no-build)
Vehicular Volumes (change from no-build)	16,150 (total) 1,045 (per lane mile)
Person Trips (change from no build)	38,713 (total) 2,504 (per lane mile)
Peak Vehicle Trips (change from no build)	12,846 (total) 831 (per lane mile)



Project 42B (**US 169**, *from TH-62 to I-394*)

Measures of Effectiveness	Value	Rank (of 24)
Throughput		
Daily new vehicles per lane mile	1,045 (vehicles)	10
Daily new persons per lane mile	2,504 (persons)	9
	Rating: **Moderate**	
Optimization		
Daily reduction in congested VMT	195,729.0 (miles)	6
Daily peak hours of delay per trip reduced	.11 (minutes)	23
Daily average travel time per trip reduced	4.57 (minutes)	4
	Rating: **Moderate**	
Reduce SOV Demand		
Change in transit mode sure	.004	7
Change in SOV use rate	- .0075	12
	Rating: **Moderate**	
Cost Effectiveness		
Benefit-cost ratio (mean)	10.45	19
Benefit-cost ratio (standard deviation)	.19	
	Rating: **Low**	
Transit Suitability		
2030 planned transit corridor	Express Bus Corridor	
Existing express bus trips	120 (total AM / PM peak periods)	6
Overall transit suitability	No significant need for ramp access, no inline stations	
	Rating: **High**	
Investment Parity		
Overall investment parity	No recent investment; corridor was not previously identified in the 2030 Plan.	
	Rating: **Moderate**	
Opportunity Rating		
Overall opportunity rating	Extensive Bus on Shoulder availability.	
	Rating: **High**	

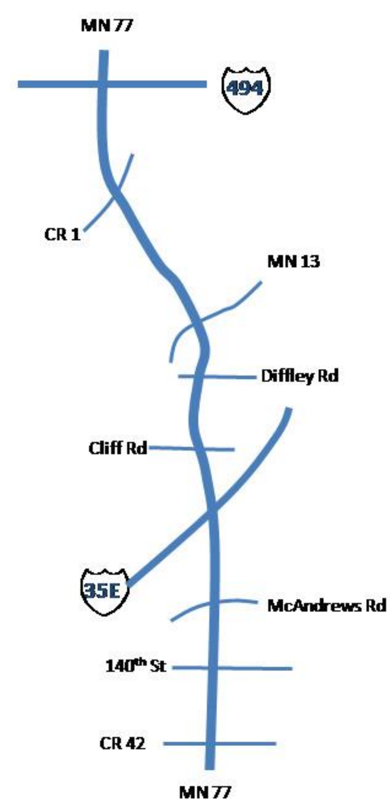
OVERALL CONCLUSION: Moderate

Project 45A: TH-77

Type	Expansion
Limits	CSAH 42 to I-494
Lane Miles	18.74
Cost Estimate	$64,083,000 (low) - $141,413,000 (high)
Cost Risk	.25 (low) - .35 (high)

Managed Lanes Type, Geometric and Other Considerations: Managed lane expansion, adding a median based managed lane in each direction. Geometric areas of concern are: 140th Street intersection geometric modifications, design exception for Minnesota River Bridge, and major challenges between Killebrew Drive and I-494.

Project Metrics	2030
Vehicle Miles of Travel	18,488,181 (build total) 69,401 (change from no-build)
Vehicle Hours of Travel	659,958 (build total) - 6,532 (change from no-build)
Vehicle Hours of Delay	310,740 (build total) 7,070 (change from no-build)
Vehicular Volumes (change from no-build)	20,151 (total) 1,075 (per lane mile)
Person Trips (change from no build)	83,091 (total) 4,434 (per lane mile)
Peak Vehicle Trips (change from no build)	13,017 (total) 695 (per lane mile)



Project 45A (**TH-77**, *from CSAH 42 to I-494*)

Measures of Effectiveness	Value	Rank (of 24)
Throughput		
Daily new vehicles per lane mile	1,075 (vehicles)	9
Daily new persons per lane mile	4,434 (persons)	5
	Rating: **High**	
Optimization		
Daily reduction in congested VMT	69,211.0 (miles)	18
Daily peak hours of delay per trip reduced	.93 (minutes)	7
Daily average travel time per trip reduced	1.61 (minutes)	22
	Rating: **Low**	
Reduce SOV Demand		
Change in transit mode sure	.001	21
Change in SOV use rate	- .0706	20
	Rating: **Low**	
Cost Effectiveness		
Benefit-cost ratio (mean)	9.31	22
Benefit-cost ratio (standard deviation)	.17	
	Rating: **Low**	
Transit Suitability		
2030 planned transit corridor	Bus Rapid Transit Corridor	
Existing express bus trips	86 (total AM / PM peak periods)	7
Overall transit suitability	Significant bus volumes on ramps may require additional accommodation with inline station location.	
	Rating: **High**	
Investment Parity		
Overall investment parity	No recent investment; corridor was not previously identified in the 2030 Plan.	
	Rating: **Moderate**	
Opportunity Rating		
Overall opportunity rating	Extensive Bus on Shoulder availability.	
	Rating: **High**	

OVERALL CONCLUSION: Moderate

Project 50A: I-494

Type	Expansion
Limits	TH-169 to I-94 / I-694
Lane Miles	30.72
Cost Estimate	$122,775,000 (low) - $148,905,000 (high)
Cost Risk	.25 (low) - .35 (high)

Managed Lanes Type, Geometric and Other Considerations: Managed lane expansion, adding a median-based managed lane in each direction. Geometric areas of concern are: a design exception at Valley View Rd overpass, widen bridge over Minnetonka Boulevard, widen bridge at I-394, widen bridge at Schmidt Lake Road, widen railroad bridge, widen bridge at County Road 47, and potential interchange modifications to improve available width.

Project Metrics	2030
Vehicle Miles of Travel	25,595,710 (build total) 134,282 (change from no-build)
Vehicle Hours of Travel	921,838 (build total) - 11,363 (change from no-build)
Vehicle Hours of Delay	451,913 (build total) 13,078 (change from no-build)
Vehicular Volumes (change from no-build)	19,247 (total) 626 (per lane mile)
Person Trips (change from no build)	17,682 (total) 576 (per lane mile)
Peak Vehicle Trips (change from no build)	15,352 (total) 500 (per lane mile)

Measures of Effectiveness	Value	Rank (of 24)
Throughput		
Daily new vehicles per lane mile	626 (vehicles)	16
Daily new persons per lane mile	576 (persons)	23
	Rating: **Low**	
Optimization		
Daily reduction in congested VMT	159,045.0 (miles)	8
Daily peak hours of delay per trip reduced	.65 (minutes)	13
Daily average travel time per trip reduced	2.3 (minutes)	14
	Rating: **Moderate**	
Reduce SOV Demand		
Change in transit mode sure	.005	4
Change in SOV use rate	.0929	2
	Rating: **High**	
Cost Effectiveness		
Benefit-cost ratio (mean)	10.27	20
Benefit-cost ratio (standard deviation)	.18	
	Rating: **Low**	
Transit Suitability		
2030 planned transit corridor	Not a transit corridor	
Existing express bus trips	0 (total AM / PM peak periods)	18
Overall transit suitability	No significant need for ramp access, no inline stations	
	Rating: **Very Low**	
Investment Parity		
Overall investment parity	Recent investment made in corridor; corridor not identified on 2030 Plan.	
	Rating: **Low**	
Opportunity Rating		
Overall opportunity rating	No existing Bus on Shoulder availability; no Bus on Shoulders are planned	
	Rating: **Low**	

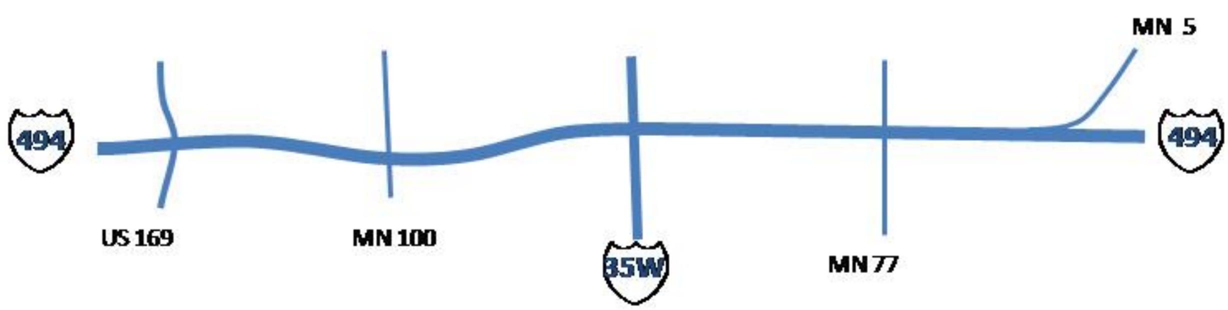
OVERALL CONCLUSION: Low

Project 53A: I-494

Type	Expansion
Limits	TH-169 to TH-5
Lane Miles	19.30
Cost Estimate	$130,875,000 (low) - $155,655,000 (high)
Cost Risk	.25 (low) - .35 (high)

Managed Lanes Type, Geometric and Other Considerations: Managed lane expansion, adding a median based managed lane in each direction. Geometric areas of concern are: interchange modification at Prairie Center Drive, interchange modification at I-35W, interchange modification at Nicollet Ave, and replacement bridge at Xerxes Avenue.

Project Metrics	2030
Vehicle Miles of Travel	28,074,099 (build total) 148,729 (change from no-build)
Vehicle Hours of Travel	995,289 (build total) - 14,809 (change from no-build)
Vehicle Hours of Delay	484,829 (build total) 16,535 (change from no-build)
Vehicular Volumes (change from no-build)	27,948 (total) 1,448 (per lane mile)
Person Trips (change from no build)	20,392 (total) 1,057 (per lane mile)
Peak Vehicle Trips (change from no build)	18,349 (total) 951 (per lane mile)



Project 53A (**I-494**, *from TH-169 to TH-5*)

Measures of Effectiveness	Value	Rank (of 24)
Throughput		
Daily new vehicles per lane mile	1,448 (vehicles)	7
Daily new persons per lane mile	1,057 (persons)	18
	Rating: **Moderate**	
Optimization		
Daily reduction in congested VMT	183,630.0 (miles)	7
Daily peak hours of delay per trip reduced	.9 (minutes)	8
Daily average travel time per trip reduced	1.86 (minutes)	19
	Rating: **High**	
Reduce SOV Demand		
Change in transit mode sure	.002	18
Change in SOV use rate	- .0969	23
	Rating: **Low**	
Cost Effectiveness		
Benefit-cost ratio (mean)	12.07	18
Benefit-cost ratio (standard deviation)	.21	
	Rating: **Low**	
Transit Suitability		
2030 planned transit corridor	Express Bus Corridor	
Existing express bus trips	0 (total AM / PM peak periods)	18
Overall transit suitability	Significant of off-corridor bus use of ramps does not necessitate inline station consideration on mainline.	
	Rating: **Low**	
Investment Parity		
Overall investment parity	Recent investment in the corridor; corridor was previously identified in the 2030 Plan.	
	Rating: **Moderate**	
Opportunity Rating		
Overall opportunity rating	Very limited Bus on Shoulders; only partial implementation planned.	
	Rating: **Low**	

OVERALL CONCLUSION: **Low**

Project 54A: TH-62

Type	Expansion
Limits	TH-169 to France Ave
Lane Miles	6.85
Cost Estimate	$54,263,000 (low) - $70,808,000 (high)
Cost Risk	.25 (low) - .35 (high)

Managed Lanes Type, Geometric and Other Considerations: Managed lane expansion, adding a median based managed lane in each direction. Geometric areas of concern are: widen bridge at TH -62/Valley View Road, and MnPass lanes not compatible with Crosstown Reconstruction design.

Project Metrics	2030
Vehicle Miles of Travel	19,892,515 (build total) - 21,712 (change from no-build)
Vehicle Hours of Travel	730,484 (build total) - 12,712 (change from no-build)
Vehicle Hours of Delay	370,501 (build total) 12,242 (change from no-build)
Vehicular Volumes (change from no-build)	14,565 (total) 2,125 (per lane mile)
Person Trips (change from no build)	32,927 (total) 4,804 (per lane mile)
Peak Vehicle Trips (change from no build)	10,438 (total) 1,523 (per lane mile)

Project 54A (**TH-62**, *from TH-169 to France Ave*)

Measures of Effectiveness	Value	Rank (of 24)
Throughput		
Daily new vehicles per lane mile	2,125 (vehicles)	2
Daily new persons per lane mile	4,804 (persons)	4
	Rating: **High**	
Optimization		
Daily reduction in congested VMT	124,711.0 (miles)	10
Daily peak hours of delay per trip reduced	1.05 (minutes)	4
Daily average travel time per trip reduced	4.83 (minutes)	3
	Rating: **High**	
Reduce SOV Demand		
Change in transit mode sure	.005	4
Change in SOV use rate	.0464	6
	Rating: **High**	
Cost Effectiveness		
Benefit-cost ratio (mean)	20.5	9
Benefit-cost ratio (standard deviation)	.36	
	Rating: **Moderate**	
Transit Suitability		
2030 planned transit corridor	Express Bus Corridor	
Existing express bus trips	86 (total AM / PM peak periods)	7
Overall transit suitability	No significant need for ramp access, no inline stations	
	Rating: **Moderate**	
Investment Parity		
Overall investment parity	No recent investment; corridor was not previously identified in the 2030 Plan.	
	Rating: **Moderate**	
Opportunity Rating		
Overall opportunity rating	No existing Bus on Shoulder availability; no Bus on Shoulders are planned	
	Rating: **Low**	

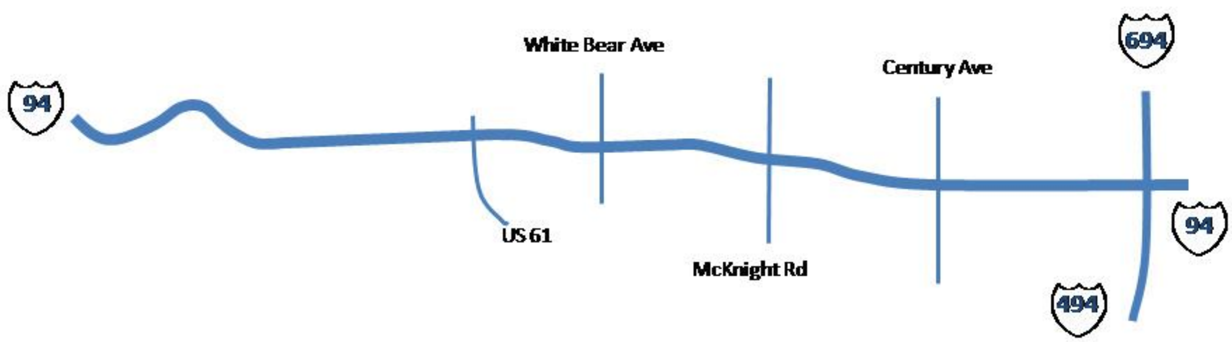
OVERALL CONCLUSION: **Moderate**

Project 55A: I-94

Type	Expansion
Limits	St. Paul CBD to I-694
Lane Miles	10.86
Cost Estimate	$133,400,000 (low) - $161,406,000 (high)
Cost Risk	.25 (low) - .35 (high)

Managed Lanes Type, Geometric and Other Considerations: Managed lane expansion, adding a median-based managed lane in each direction. Geometric areas of concern are: a realignment of eastbound lane under Mounds Boulevard exit ramp, design exception at Mounds Boulevard overpass and exit ramp, widen bridge at numerous locations throughout corridor.

Project Metrics	2030
Vehicle Miles of Travel	13,160,854 (build total) - 1,868 (change from no-build)
Vehicle Hours of Travel	414,306 (build total) - 3,724 (change from no-build)
Vehicle Hours of Delay	163,592 (build total) 3,515 (change from no-build)
Vehicular Volumes (change from no-build)	3,895 (total) 359 (per lane mile)
Person Trips (change from no build)	8,518 (total) 784 (per lane mile)
Peak Vehicle Trips (change from no build)	2,825 (total) 260 (per lane mile)



Measures of Effectiveness	Value	Rank (of 24)
Throughput		
Daily new vehicles per lane mile	359 (vehicles)	20
Daily new persons per lane mile	784 (persons)	21
	Rating: **Low**	
Optimization		
Daily reduction in congested VMT	35,257.0 (miles)	20
Daily peak hours of delay per trip reduced	.12 (minutes)	22
Daily average travel time per trip reduced	.98 (minutes)	24
	Rating: **Low**	
Reduce SOV Demand		
Change in transit mode sure	.0	24
Change in SOV use rate	- .1711	24
	Rating: **Low**	
Cost Effectiveness		
Benefit-cost ratio (mean)	3.09	24
Benefit-cost ratio (standard deviation)	.05	
	Rating: **Low**	
Transit Suitability		
2030 planned transit corridor	Bus Rapid Transit Corridor	
Existing express bus trips	67 (total AM / PM peak periods)	10
Overall transit suitability	Significant use of ramps by buses; multiple inline stations identified in MetroTransit plan.	
	Rating: **High**	
Investment Parity		
Overall investment parity	No recent investment; corridor was not previously identified in the 2030 Plan.	
	Rating: **Moderate**	
Opportunity Rating		
Overall opportunity rating	Limited Bus on Shoulders, completion planned.	
	Rating: **Moderate**	

OVERALL CONCLUSION: **Low**

Project «ID__Priority» (**«Highway»**, *from «Beginning» to «End»*)

APPENDIX B: COST ESTIMATION AND EFFECTIVENESS SUMMARIES BY CORRIDOR

Project 1B

Benefit Cost

Table 1

Summary

Project 1B	Low		High	
Operating Benefit	$	36,059,047	$	36,059,047
Travel Time Benefit	$	206,856,047	$	206,856,047
Operating and Maintenance Benefit	$	(2,904,287)	$	3,773,121
Total Benefit	**$**	**240,010,807**	**$**	**246,688,215**
Mill and Overlay	$	1,560,000	$	1,560,000
Managed Lanes	$	975,000	$	1,300,000
Grading and Drainage	$	455,000	$	1,300,000
Major Structures	$	500,000	$	1,000,000
Utilities	$	-	$	370,500
Miscellaneous Items	$	1,300,000	$	3,900,000
Right of Way	$	-	$	-
Risk Factor (35%)	$	1,677,000	$	3,301,000
Engineering (18%)	$	1,164,000	$	2,292,000
Total Cost	**$**	**7,631,000**	**$**	**15,023,500**
PV Total Cost	$	7,631,000	$	15,023,500
Project Salvage Value	$	851,221	$	1,451,795
(PV Total Cost - Salvage Value)	**$**	**6,779,779**	**$**	**13,571,705**
Benefit-Cost Ratio	**35.40**		**18.18**	

Project 3A

Benefit Cost
Table 1
Summary

Project 3A	Low		High	
Operating Benefit	$	93,949,190	$	93,949,190
Travel Time Benefit	$	519,285,022	$	519,285,022
Operating and Maintenance Benefit	$	12,999,808	$	44,503,476
Total Benefit	**$**	**626,234,020**	**$**	**657,737,688**
Mill and Overlay	$	18,400,000	$	18,400,000
Managed Lanes	$	3,450,000	$	4,600,000
Grading and Drainage	$	1,610,000	$	4,600,000
Major Structures	$	1,875,000	$	3,750,000
Utilities	$	-	$	1,311,000
Miscellaneous Items	$	4,600,000	$	13,800,000
Right of Way	$	-	$	-
Risk Factor (35%)	$	10,477,000	$	16,261,000
Engineering (18%)	$	7,274,000	$	11,290,000
Total Cost	**$**	**47,686,000**	**$**	**74,012,000**
PV Total Cost	$	47,686,000	$	74,012,000
Project Salvage Value	$	4,651,392	$	6,818,286
(PV Total Cost - Salvage Value)	**$**	**43,034,608**	**$**	**67,193,714**
Benefit-Cost Ratio	**14.55**		**9.79**	

Project 4A

Benefit Cost
Table 1
Summary

Project 4A	Low		High	
Operating Benefit	$	140,023,692	$	140,023,692
Travel Time Benefit	$	752,388,883	$	752,388,883
Operating and Maintenance Benefit	$	33,582,689	$	71,592,549
Total Benefit	**$**	**925,995,264**	**$**	**964,005,124**
Mill and Overlay	$	-	$	-
Managed Lanes	$	5,550,000	$	7,400,000
Grading and Drainage	$	-	$	-
Major Structures	$	-	$	-
Utilities	$	-	$	2,109,000
Miscellaneous Items	$	-	$	-
Right of Way	$	-	$	-
Risk Factor (35%)	$	1,943,000	$	3,328,000
Engineering (18%)	$	1,349,000	$	2,311,000
Total Cost	**$**	**8,842,000**	**$**	**15,148,000**
PV Total Cost	$	8,842,000	$	15,148,000
Project Salvage Value	$	1,686,970	$	2,249,293
(PV Total Cost - Salvage Value)	**$**	**7,155,030**	**$**	**12,898,707**
Benefit-Cost Ratio	**129.42**		**74.74**	

Project 6B

Benefit Cost
Table 1
Summary

Project 6B	Low		High	
Operating Benefit	$	96,991,725	$	96,991,725
Travel Time Benefit	$	192,605,156	$	192,605,156
Operating and Maintenance Benefit	$	(16,975,136)	$	8,707,202
Total Benefit	**$**	**272,621,745**	**$**	**298,304,083**
Mill and Overlay	$	3,600,000	$	3,600,000
Managed Lanes	$	2,250,000	$	3,000,000
Grading and Drainage	$	1,050,000	$	3,000,000
Major Structures	$	-	$	-
Utilities	$	-	$	855,000
Miscellaneous Items	$	3,000,000	$	9,000,000
Right of Way	$	-	$	-
Risk Factor (35%)	$	3,465,000	$	6,809,000
Engineering (18%)	$	2,406,000	$	4,728,000
Total Cost	**$**	**15,771,000**	**$**	**30,992,000**
PV Total Cost	$	15,771,000	$	30,992,000
Project Salvage Value	$	1,508,500	$	2,438,582
(PV Total Cost - Salvage Value)	**$**	**14,262,500**	**$**	**28,553,418**
Benefit-Cost Ratio	**19.11**		**10.45**	

Project 7B

Benefit Cost
Table 1
Summary

Project 7B	Low		High	
Operating Benefit	$	248,980,097	$	248,980,097
Travel Time Benefit	$	1,521,209,916	$	1,521,209,916
Operating and Maintenance Benefit	$	55,955,697	$	191,558,442
Total Benefit	**$**	**1,826,145,710**	**$**	**1,961,748,455**
Mill and Overlay	$	79,200,000	$	79,200,000
Managed Lanes	$	14,850,000	$	19,800,000
Grading and Drainage	$	6,930,000	$	19,800,000
Major Structures	$	9,560,000	$	19,120,000
Utilities	$	-	$	5,643,000
Miscellaneous Items	$	19,800,000	$	59,400,000
Right of Way	$	-	$	-
Risk Factor (35%)	$	45,619,000	$	71,037,000
Engineering (18%)	$	31,673,000	$	49,320,000
Total Cost	**$**	**207,632,000**	**$**	**323,320,000**
PV Total Cost	$	207,632,000	$	323,320,000
Project Salvage Value	$	20,609,614	$	30,525,085
(PV Total Cost - Salvage Value)	**$**	**187,022,386**	**$**	**292,794,915**
Benefit-Cost Ratio		**9.76**		**6.70**

Project 10A

Benefit Cost
Table 1
Summary

Project 10A	Low		High	
Operating Benefit	$	97,607,045	$	97,607,045
Travel Time Benefit	$	671,246,054	$	671,246,054
Operating and Maintenance Benefit	$	17,521,481	$	59,982,946
Total Benefit	**$**	**786,374,580**	**$**	**828,836,046**
Mill and Overlay	$	24,800,000	$	24,800,000
Managed Lanes	$	4,650,000	$	6,200,000
Grading and Drainage	$	2,170,000	$	6,200,000
Major Structures	$	6,300,000	$	12,600,000
Utilities	$	-	$	5,643,000
Miscellaneous Items	$	6,200,000	$	18,600,000
Right of Way	$	-	$	-
Risk Factor (35%)	$	15,442,000	$	25,915,000
Engineering (18%)	$	10,721,000	$	17,992,000
Total Cost	**$**	**70,283,000**	**$**	**117,950,000**
PV Total Cost	$	70,283,000	$	117,950,000
Project Salvage Value	$	7,759,820	$	12,170,970
(PV Total Cost - Salvage Value)	**$**	**62,523,180**	**$**	**105,779,030**
Benefit-Cost Ratio	**12.58**		**7.84**	

Project 17A

Benefit Cost
Table 1
Summary

Project 17A	Low		High	
Operating Benefit	$	107,987,648	$	107,987,648
Travel Time Benefit	$	968,915,178	$	968,915,178
Operating and Maintenance Benefit	$	24,506,286	$	52,243,211
Total Benefit	**$**	**1,242,440,129**	**$**	**1,269,892,059**
Mill and Overlay	$	-	$	-
Managed Lanes	$	4,050,000	$	5,400,000
Grading and Drainage	$	-	$	-
Major Structures	$	-	$	-
Utilities	$	-	$	1,539,000
Miscellaneous Items	$	-	$	-
Right of Way	$	-	$	-
Risk Factor (35%)	$	1,418,000	$	2,429,000
Engineering (18%)	$	984,000	$	1,686,000
Total Cost	**$**	**6,452,000**	**$**	**11,054,000**
PV Total Cost	$	6,452,000	$	11,054,000
Project Salvage Value	$	1,231,032	$	1,641,376
(PV Total Cost - Salvage Value)	**$**	**5,220,968**	**$**	**9,412,624**
Benefit-Cost Ratio	**237.97**		**134.91**	

Project 18A

Benefit Cost

Table 1

Summary

Project 18A	Low		High	
Operating Benefit	$	102,927,756	$	102,927,756
Travel Time Benefit	$	945,066,748	$	945,066,748
Operating and Maintenance Benefit	$	38,614,864	$	98,197,888
Total Benefit	**$**	**1,086,609,368**	**$**	**1,146,192,392**
Mill and Overlay	$	40,600,000	$	40,600,000
Managed Lanes	$	8,700,000	$	11,600,000
Grading and Drainage	$	4,060,000	$	11,600,000
Major Structures	$	2,503,000	$	5,006,000
Utilities	$	-	$	3,306,000
Miscellaneous Items	$	11,600,000	$	34,800,000
Right of Way	$	-	$	-
Risk Factor (35%)	$	23,612,000	$	37,419,000
Engineering (18%)	$	16,394,000	$	25,980,000
Total Cost	**$**	**107,469,000**	**$**	**170,311,000**
PV Total Cost	$	107,469,000	$	170,311,000
Project Salvage Value	$	10,131,037	$	14,716,232
(PV Total Cost - Salvage Value)	**$**	**97,337,963**	**$**	**155,594,768**
Benefit-Cost Ratio		**11.16**		**7.37**

Project 19A

Benefit Cost Table 1 Summary				
Project 19A	**Low**		**High**	
Operating Benefit	$	9,171,253	$	9,171,253
Travel Time Benefit	$	495,436,592	$	495,436,592
Operating and Maintenance Benefit	$	33,288,676	$	84,653,352
Total Benefit	**$**	**537,896,521**	**$**	**589,261,197**
Mill and Overlay	$	35,000,000	$	35,000,000
Managed Lanes	$	7,500,000	$	10,000,000
Grading and Drainage	$	3,500,000	$	10,000,000
Major Structures	$	5,227,500	$	10,455,000
Utilities	$	-	$	2,850,000
Miscellaneous Items	$	10,000,000	$	30,000,000
Right of Way	$	-	$	-
Risk Factor (35%)	$	21,430,000	$	34,407,000
Engineering (18%)	$	14,878,000	$	23,888,000
Total Cost	**$**	**97,535,500**	**$**	**156,600,000**
PV Total Cost	$	97,535,500	$	156,600,000
Project Salvage Value	$	9,946,434	$	15,111,969
(PV Total Cost - Salvage Value)	**$**	**87,589,066**	**$**	**141,488,031**
Benefit-Cost Ratio	**6.14**		**4.16**	

Project 20B

Benefit Cost

Table 1

Summary

Project 20B	Low		High	
Operating Benefit	$	140,023,692	$	140,023,692
Travel Time Benefit	$	752,388,883	$	752,388,883
Operating and Maintenance Benefit	$	22,608,362	$	77,397,350
Total Benefit	**$**	**915,020,938**	**$**	**969,809,926**
Mill and Overlay	$	32,000,000	$	32,000,000
Managed Lanes	$	6,000,000	$	8,000,000
Grading and Drainage	$	2,800,000	$	8,000,000
Major Structures	$	22,050,000	$	44,100,000
Utilities	$	-	$	2,280,000
Miscellaneous Items	$	8,000,000	$	24,000,000
Right of Way	$	-	$	-
Risk Factor (35%)	$	24,798,000	$	41,433,000
Engineering (18%)	$	17,217,000	$	28,766,000
Total Cost	**$**	**112,865,000**	**$**	**188,579,000**
PV Total Cost	$	112,865,000	$	188,579,000
Project Salvage Value	$	15,512,511	$	26,704,157
(PV Total Cost - Salvage Value)	**$**	**97,352,489**	**$**	**161,874,843**
Benefit-Cost Ratio	**9.40**		**5.99**	

Project 21B

Benefit Cost
Table 1
Summary

Project 21B	Low	High
Operating Benefit	$ 294,943,884	$ 294,943,884
Travel Time Benefit	$ 1,575,014,301	$ 1,575,014,301
Operating and Maintenance Benefit	$ 48,607,979	$ 166,404,303
Total Benefit	**$ 1,918,566,165**	**$ 2,036,362,489**
Mill and Overlay	$ 68,800,000	$ 68,800,000
Managed Lanes	$ 12,900,000	$ 17,200,000
Grading and Drainage	$ 6,020,000	$ 17,200,000
Major Structures	$ -	$ -
Utilities	$ -	$ 4,902,000
Miscellaneous Items	$ 17,200,000	$ 51,600,000
Right of Way	$ -	$ -
Risk Factor (35%)	$ 36,722,000	$ 55,896,000
Engineering (18%)	$ 25,496,000	$ 38,808,000
Total Cost	**$ 167,138,000**	**$ 254,406,000**
PV Total Cost	$ 167,138,000	$ 254,406,000
Project Salvage Value	$ 14,622,335	$ 19,954,808
(PV Total Cost - Salvage Value)	**$ 152,515,665**	**$ 234,451,192**
Benefit-Cost Ratio	**12.58**	**8.69**

Project 22B

Benefit Cost

Table 1

Summary

Project 22B	Low		High	
Operating Benefit	$	38,814,149	$	38,814,149
Travel Time Benefit	$	352,127,886	$	352,127,886
Operating and Maintenance Benefit	$	(9,076,313)	$	6,675,521
Total Benefit	**$**	**381,865,722**	**$**	**397,617,556**
Mill and Overlay	$	2,760,000	$	2,760,000
Managed Lanes	$	1,725,000	$	2,300,000
Grading and Drainage	$	805,000	$	2,300,000
Major Structures	$	-	$	-
Utilities	$	-	$	655,500
Miscellaneous Items	$	2,300,000	$	6,900,000
Right of Way	$	-	$	-
Risk Factor (35%)	$	2,657,000	$	5,220,000
Engineering (18%)	$	1,844,000	$	3,624,000
Total Cost	**$**	**12,091,000**	**$**	**23,759,500**
PV Total Cost	$	12,091,000	$	23,759,500
Project Salvage Value	$	1,156,516	$	1,869,580
(PV Total Cost - Salvage Value)	**$**	**10,934,484**	**$**	**21,889,920**
Benefit-Cost Ratio	**34.92**		**18.16**	

Project 23A

Benefit Cost

Table 1

Summary

Project 23A	Low	High
Operating Benefit	$ 117,790,190	$ 117,790,190
Travel Time Benefit	$ 861,233,699	$ 861,233,699
Operating and Maintenance Benefit	$ 29,555,260	$ 151,118,326
Total Benefit	**$ 1,008,579,149**	**$ 1,130,142,216**
Mill and Overlay	$ 62,480,000	$ 62,480,000
Managed Lanes	$ 10,650,000	$ 14,200,000
Grading and Drainage	$ 4,970,000	$ 14,200,000
Major Structures	$ 4,800,000	$ 9,600,000
Utilities	$ -	$ 4,047,000
Miscellaneous Items	$ 14,200,000	$ 42,600,000
Right of Way	$ -	$ -
Risk Factor (35%)	$ 33,985,000	$ 51,494,000
Engineering (18%)	$ 23,595,000	$ 35,752,000
Total Cost	**$ 154,680,000**	**$ 234,373,000**
PV Total Cost	$ 154,680,000	$ 234,373,000
Project Salvage Value	$ 14,672,820	$ 20,971,576
(PV Total Cost - Salvage Value)	**$ 140,007,180**	**$ 213,401,424**
Benefit-Cost Ratio	**7.20**	**5.30**

Project 26B

Benefit Cost
Table 1
Summary

Project 26B	Low	High
Operating Benefit	$ 27,784,160	$ 27,784,160
Travel Time Benefit	$ 252,444,357	$ 252,444,357
Operating and Maintenance Benefit	$ (1,563,847)	$ 2,031,680
Total Benefit	**$ 278,664,670**	**$ 282,260,197**
Mill and Overlay	$ 840,000	$ 840,000
Managed Lanes	$ 525,000	$ 700,000
Grading and Drainage	$ 245,000	$ 700,000
Major Structures	$ -	$ -
Utilities	$ -	$ 199,500
Miscellaneous Items	$ 1,200,000	$ 2,200,000
Right of Way	$ -	$ -
Risk Factor (35%)	$ 984,000	$ 1,624,000
Engineering (18%)	$ 683,000	$ 1,127,000
Total Cost	**$ 4,477,000**	**$ 7,390,500**
PV Total Cost	$ 4,477,000	$ 7,390,500
Project Salvage Value	$ 351,983	$ 569,003
(PV Total Cost - Salvage Value)	**$ 4,125,017**	**$ 6,821,497**
Benefit-Cost Ratio	**67.55**	**41.38**

Project 27A

Benefit Cost
Table 1
Summary

Project 27A	Low		High	
Operating Benefit	$	239,067,904	$	239,067,904
Travel Time Benefit	$	1,170,318,077	$	1,170,318,077
Operating and Maintenance Benefit	$	31,291,355	$	79,574,151
Total Benefit	**$**	**1,440,677,337**	**$**	**1,488,960,132**
Mill and Overlay	$	32,900,000	$	32,900,000
Managed Lanes	$	7,050,000	$	9,400,000
Grading and Drainage	$	3,290,000	$	9,400,000
Major Structures	$	6,000,000	$	12,000,000
Utilities	$	-	$	2,679,000
Miscellaneous Items	$	9,400,000	$	28,200,000
Right of Way	$	-	$	-
Risk Factor (35%)	$	20,524,000	$	33,103,000
Engineering (18%)	$	14,250,000	$	22,983,000
Total Cost	**$**	**93,414,000**	**$**	**150,665,000**
PV Total Cost	$	93,414,000	$	150,665,000
Project Salvage Value	$	9,778,760	$	15,063,474
(PV Total Cost - Salvage Value)	**$**	**83,635,240**	**$**	**135,601,526**
Benefit-Cost Ratio	**17.23**		**10.98**	

Project 28B

Benefit Cost

Table 1

Summary

Project 28B	Low		High	
Operating Benefit	$	321,936,006	$	321,936,006
Travel Time Benefit	$	1,736,354,747	$	1,736,354,747
Operating and Maintenance Benefit	$	43,275,279	$	110,049,357
Total Benefit	**$**	**2,101,566,031**	**$**	**2,168,340,110**
Mill and Overlay	$	45,500,000	$	45,500,000
Managed Lanes	$	9,750,000	$	13,000,000
Grading and Drainage	$	4,550,000	$	13,000,000
Major Structures	$	4,680,000	$	9,360,000
Utilities	$	-	$	3,705,000
Miscellaneous Items	$	13,000,000	$	39,000,000
Right of Way	$	-	$	-
Risk Factor (35%)	$	27,118,000	$	43,248,000
Engineering (18%)	$	18,828,000	$	30,026,000
Total Cost	**$**	**123,426,000**	**$**	**196,839,000**
PV Total Cost	$	123,426,000	$	196,839,000
Project Salvage Value	$	12,094,482	$	17,973,796
(PV Total Cost - Salvage Value)	**$**	**111,331,518**	**$**	**178,865,204**
Benefit-Cost Ratio	**18.88**		**12.12**	

Project 29B

Benefit Cost
Table 1
Summary

Project 29B	Low		High	
Operating Benefit	$	113,515,949	$	113,515,949
Travel Time Benefit	$	1,019,374,965	$	1,019,374,965
Operating and Maintenance Benefit	$	53,927,655	$	137,138,430
Total Benefit	**$**	**1,186,818,570**	**$**	**1,270,029,345**
Mill and Overlay	$	56,700,000	$	56,700,000
Managed Lanes	$	12,150,000	$	16,200,000
Grading and Drainage	$	5,670,000	$	16,200,000
Major Structures	$	8,870,000	$	17,740,000
Utilities	$	-	$	4,617,000
Miscellaneous Items	$	16,200,000	$	48,600,000
Right of Way	$	-	$	-
Risk Factor (35%)	$	34,857,000	$	56,020,000
Engineering (18%)	$	24,200,000	$	38,894,000
Total Cost	**$**	**158,647,000**	**$**	**254,971,000**
PV Total Cost	$	158,647,000	$	254,971,000
Project Salvage Value	$	16,271,826	$	24,798,596
(PV Total Cost - Salvage Value)	**$**	**142,375,174**	**$**	**230,172,404**
Benefit-Cost Ratio		**8.34**		**5.52**

Project 41A

Benefit Cost
Table 1
Summary

Project 41A	Low		High	
Operating Benefit	$	23,457,756	$	23,457,756
Travel Time Benefit	$	577,161,090	$	577,161,090
Operating and Maintenance Benefit	$	43,941,052	$	111,742,424
Total Benefit	**$**	**644,559,897**	**$**	**712,361,270**
Mill and Overlay	$	46,200,000	$	46,200,000
Managed Lanes	$	9,900,000	$	13,200,000
Grading and Drainage	$	4,620,000	$	13,200,000
Major Structures	$	12,600,000	$	25,200,000
Utilities	$	-	$	3,762,000
Miscellaneous Items	$	13,200,000	$	39,600,000
Right of Way	$	-	$	-
Risk Factor (35%)	$	30,282,000	$	49,407,000
Engineering (18%)	$	21,024,000	$	34,302,000
Total Cost	**$**	**137,826,000**	**$**	**224,871,000**
PV Total Cost	$	137,826,000	$	224,871,000
Project Salvage Value	$	15,381,107	$	24,451,428
(PV Total Cost - Salvage Value)	**$**	**122,444,893**	**$**	**200,419,572**
Benefit-Cost Ratio	**5.26**		**3.55**	

Project 42B

Benefit Cost

Table 1

Summary

Project 42B	Low		High	
Operating Benefit	$	208,366,828	$	208,366,828
Travel Time Benefit	$	1,172,572,045	$	1,172,572,045
Operating and Maintenance Benefit	$	37,283,317	$	94,811,754
Total Benefit	**$**	**1,418,222,190**	**$**	**1,475,750,627**
Mill and Overlay	$	39,200,000	$	39,200,000
Managed Lanes	$	8,400,000	$	11,200,000
Grading and Drainage	$	3,920,000	$	11,200,000
Major Structures	$	72,165,000	$	144,330,000
Utilities	$	-	$	3,192,000
Miscellaneous Items	$	11,200,000	$	33,600,000
Right of Way	$	-	$	-
Risk Factor (35%)	$	47,210,000	$	84,953,000
Engineering (18%)	$	32,777,000	$	58,982,000
Total Cost	**$**	**214,872,000**	**$**	**386,657,000**
PV Total Cost	$	214,872,000	$	386,657,000
Project Salvage Value	$	37,337,573	$	69,320,540
(PV Total Cost - Salvage Value)	**$**	**177,534,427**	**$**	**317,336,460**
Benefit-Cost Ratio	**7.99**		**4.65**	

Project 45A

Benefit Cost

Table 1

Summary

Project 45A	Low		High	
Operating Benefit	$	73,679,815	$	73,679,815
Travel Time Benefit	$	514,050,000	$	514,050,000
Operating and Maintenance Benefit	$	52,564,443	$	179,948,839
Total Benefit	**$**	**640,294,258**	**$**	**767,678,655**
Mill and Overlay	$	74,400,000	$	74,400,000
Managed Lanes	$	13,950,000	$	18,600,000
Grading and Drainage	$	6,510,000	$	18,600,000
Major Structures	$	60,000,000	$	120,000,000
Utilities	$	-	$	5,301,000
Miscellaneous Items	$	18,600,000	$	55,800,000
Right of Way	$	-	$	-
Risk Factor (35%)	$	60,711,000	$	102,445,000
Engineering (18%)	$	42,151,000	$	71,126,000
Total Cost	**$**	**276,322,000**	**$**	**466,272,000**
PV Total Cost	$	276,322,000	$	466,272,000
Project Salvage Value	$	39,517,083	$	68,988,154
(PV Total Cost - Salvage Value)	**$**	**236,804,917**	**$**	**397,283,846**
Benefit-Cost Ratio		**2.70**		**1.93**

Project 50A

Benefit Cost
Table 1
Summary

Project 50A	Low	High
Operating Benefit	$ 169,314,216	$ 169,314,216
Travel Time Benefit	$ 950,883,438	$ 950,883,438
Operating and Maintenance Benefit	$ 50,868,816	$ 174,144,038
Total Benefit	**$ 1,171,066,469**	**$ 1,294,341,692**
Mill and Overlay	$ 72,000,000	$ 72,000,000
Managed Lanes	$ 13,500,000	$ 18,000,000
Grading and Drainage	$ 6,300,000	$ 18,000,000
Major Structures	$ 2,400,000	$ 4,800,000
Utilities	$ -	$ 5,130,000
Miscellaneous Items	$ 18,000,000	$ 54,000,000
Right of Way	$ -	$ -
Risk Factor (35%)	$ 39,270,000	$ 60,176,000
Engineering (18%)	$ 27,265,000	$ 41,779,000
Total Cost	**$ 178,735,000**	**$ 273,885,000**
PV Total Cost	$ 178,735,000	$ 273,885,000
Project Salvage Value	$ 16,250,626	$ 22,779,304
(PV Total Cost - Salvage Value)	**$ 162,484,374**	**$ 251,105,696**
Benefit-Cost Ratio	**7.21**	**5.15**

Project 53A

Benefit Cost
Table 1
Summary

Project 53A	Low		High	
Operating Benefit	$	195,486,620	$	195,486,620
Travel Time Benefit	$	1,202,237,165	$	1,202,237,165
Operating and Maintenance Benefit	$	50,868,816	$	174,144,038
Total Benefit	**$**	**1,448,592,601**	**$**	**1,571,867,823**
Mill and Overlay	$	72,000,000	$	72,000,000
Managed Lanes	$	13,500,000	$	18,000,000
Grading and Drainage	$	6,300,000	$	18,000,000
Major Structures	$	6,300,000	$	12,600,000
Utilities	$	-	$	5,130,000
Miscellaneous Items	$	18,000,000	$	54,000,000
Right of Way	$	-	$	-
Risk Factor (35%)	$	40,635,000	$	62,906,000
Engineering (18%)	$	28,212,000	$	43,674,000
Total Cost	**$**	**184,947,000**	**$**	**286,310,000**
PV Total Cost	$	184,947,000	$	286,310,000
Project Salvage Value	$	17,791,422	$	25,860,896
(PV Total Cost - Salvage Value)	**$**	**167,155,578**	**$**	**260,449,104**
Benefit-Cost Ratio		**8.67**		**6.04**

Project 54A

Benefit Cost
Table 1
Summary

Project 54A	Low	High
Operating Benefit	$ 132,763,339	$ 132,763,339
Travel Time Benefit	$ 890,099,025	$ 890,099,025
Operating and Maintenance Benefit	$ 23,302,073	$ 59,257,346
Total Benefit	**$ 1,046,164,436**	**$ 1,082,119,710**
Mill and Overlay	$ 24,500,000	$ 24,500,000
Managed Lanes	$ 5,250,000	$ 7,000,000
Grading and Drainage	$ 2,450,000	$ 7,000,000
Major Structures	$ 7,575,000	$ 15,150,000
Utilities	$ -	$ 1,995,000
Miscellaneous Items	$ 7,000,000	$ 21,000,000
Right of Way	$ -	$ -
Risk Factor (35%)	$ 16,371,000	$ 26,826,000
Engineering (18%)	$ 11,366,000	$ 18,625,000
Total Cost	**$ 74,512,000**	**$ 122,096,000**
PV Total Cost	$ 74,512,000	$ 122,096,000
Project Salvage Value	$ 8,509,523	$ 13,672,416
(PV Total Cost - Salvage Value)	**$ 66,002,477**	**$ 108,423,584**
Benefit-Cost Ratio	**15.85**	**9.98**

Project 55A

Benefit Cost
Table 1
Summary

Project 55A	Low		High	
Operating Benefit	$	37,533,474	$	37,533,474
Travel Time Benefit	$	255,570,828	$	255,570,828
Operating and Maintenance Benefit	$	38,434,216	$	131,575,495
Total Benefit	**$**	**331,538,517**	**$**	**424,679,797**
Mill and Overlay	$	54,400,000	$	54,400,000
Managed Lanes	$	10,200,000	$	13,600,000
Grading and Drainage	$	4,760,000	$	13,600,000
Major Structures	$	35,190,000	$	70,380,000
Utilities	$	-	$	3,876,000
Miscellaneous Items	$	13,600,000	$	40,800,000
Right of Way	$	-	$	-
Risk Factor (35%)	$	41,353,000	$	68,830,000
Engineering (18%)	$	28,711,000	$	47,787,000
Total Cost	**$**	**188,214,000**	**$**	**313,273,000**
PV Total Cost	$	188,214,000	$	313,273,000
Project Salvage Value	$	25,464,570	$	43,583,668
(PV Total Cost - Salvage Value)	**$**	**162,749,430**	**$**	**269,689,332**
Benefit-Cost Ratio		**2.04**		**1.57**

APPENDIX C: MHSIS GUIDING PRINCIPLES (PMT MEMORANDUM)

November 18, 2009

Metropolitan Highway System Investment Study: Policy Direction and Guiding Principles

In 2008, Metro District and the Metropolitan Council completed the "Principal Arterial (PA) Study" to answer questions related to future mobility needs in the region. One of the key conclusions of the study was that "building our way out of congestion" is not a feasible approach and would cost at least $40 billion.

The current Transportation Policy Plan (TPP) and Mn/DOT's Metro District Investment Plans indicate the region will receive $900 million over the next 20 years for mobility investments. Traditional project design standards and practices call for projects to be designed to eliminate congestion for a 20-year forecast horizon. The PA Study concluded that a lower-cost/high-benefit approach may be an effective way to address specific problems, and that pricing can help manage demand and provide an alternative to congestion in some corridors.

The policy direction recorded below is taken from the Council TPP and the Mn/DOT State Plan. These policies have provided the basis for the investment principles that have, and will continue to be used, to develop project recommendations for the MHSIS 50-year vision. They will also provide direction as the 50-year vision is refined and projects are prioritized to produce the 20-year fiscally-constrained plans.

These investment principles have been developed through close consultation between the Metropolitan Council and Mn/DOT. These principles are intended to change the approach to determining how projects are developed and where investments are made in the future.

Policy direction

- There are, and will continue to be, fiscal constraints for Mn/DOT and the Council.
- Building our way out of congestion is not feasible; few if any projects should be undertaken with this objective.
- A balanced approach toward investments is needed, which includes:
    - Preservation
    - Safety
    - Mobility
        - Operational and Management Techniques, including ITS
        - Congestion Management Safety Projects
        - Strategic Capacity Enhancements
    - Regional & Community Improvement Projects (RCIP's)
- Develop plans that result in a multimodal highway system.
- Strive to integrate CMSP projects with preservation projects.
    - When possible, integrate preservation elements into all system improvements
- Operational techniques, including pricing, provide effective tools to manage the highway facilities, manage demand and provide alternatives to congestion.

- Major projects will be reassessed to determine if the critical preservation, safety and mobility elements can be addressed with a lower-cost/high benefit solution.

Investment Principles

- The projects on the vision map need to be refined and their priority established given the anticipated resources.
    - The design and scale of projects needs to be refined.
    - Right-of-way costs must be considered early in project development and prioritization.
    - The needs of existing development with new development must be balanced in project selection.

- Utilize the most cost-effective operational and management techniques to optimize system performance.
    - Management and ITS applications will be used to their fullest extent to improve mobility and relieve congestion before adding new capacity.
    - Upcoming CMSP projects will not preclude identified MHSIS projects, and MHSIS project will not preclude planned/future CMSP projects.

- Managed lanes are a higher priority for improvement than general purpose lanes.
    - There are many types of non-priced managed lanes.
    - Capacity/mobility projects that contain an element of management or pricing will receive priority
    - Projects that include a transit advantage will receive priority

- There are some areas where traditional capacity will not be added; this does not preclude management, operational and pricing solutions.
    - Management solutions (eg., pricing, Dynamic Shoulder Lanes, Priced Dynamic Shoulder Lanes, Intelligent Transportation Systems, Ramp Meters) are tools that can add capacity and increase mobility on the system without the need to add additional lanes.

- Needed segments of general purpose lanes can be converted to managed lanes.
    - It may be necessary in some situations to convert sections of general purpose lanes into managed lanes to maintain managed/priced lane continuity
    - This action may require legislative action.

- Highway improvements should enhance and support transit use where existing or planned express transit service exists.

- The conversion of right-side bus shoulders to left-side lanes may benefit transit and expand use to HOVs or those willing to pay.

- Design exceptions may be needed to accommodate an improvement or project within the existing right-of-way. Overall safety must be improved.

- Complete the six-lane beltway and unfinished connections to utilize existing and planned investments.
    - This has been a long standing policy with the Department and the Metropolitan Council.
    - Additional six-lane segments of the beltway may be managed lanes.

- Do not add inbound capacity outside the beltway that cannot be accommodated by projects or operational changes/strategies on, or within, the beltway.
    - Do not bring added demand into an area that cannot be accommodated by the existing system or with programmed improvements.
    - An option may be to add transit advantages or other managed outbound lanes.
    - Phased project implementation may be necessary to complete the 50-year vision.

- Manage access to IRC's or other Principal Arterials.
    - Reducing access points and/or signalized intersections will mean easier freeway conversion in the future; this does not preclude the addition of new signals for safety reasons.

- Conversion of expressways to freeways should occur, working from the inside of the region to the outside to avoid creating gaps.
    - Any conversion of an intersection to an interchange must be identified in the TPP and Metro District Investment plan.

- Two-mile interchange spacing outside the beltway, one-mile spacing on, or inside the beltway. This includes opportunity-driven removal and/or consolidation of interchanges recognizing:
    - Interchange spacing is important to maintain and/or improve traffic flow.
    - The interchange must connect with at least an A-Minor arterial

- Jurisdictional responsibility is yet to be determined for new principal arterials.
    - With regional growth extending further outward from the core, there is the desire for additional principal arterials outside the beltway."
    - New principal arterials outside the beltway have been under consideration for some time.

APPENDIX D: TRAVEL DEMAND FORECASTING MODEL TECH MEMORANDUM

Memorandum To: Project Files

From: Steve Ruegg, PB

Date: March 15, 2010 (DRAFT)

Subject: **MHSIS Travel Demand Forecasting Evaluation Methodology**

Introduction:

This memorandum describes the methodology used to develop performance measures for transportation system improvements that were identified as a part of the Metropolitan Highway System Investment Study (MHSIS). The MHSIS was a study by the Metropolitan Council (the Council) and the Minnesota Department of Transportation (MnDOT) to develop a new approach to long term transportation investments for the Twin Cities Metropolitan area. This approach explicitly recognized that funding for transportation infrastructure will not be sufficient to eliminate or even reduce current congestion for the overall system for the foreseeable future. Given this, the challenge of the study was to change the way in which we evaluate and prioritize investments with the resources we do have available to maximize cost effectiveness in the broadest terms.

A key part of this study was to systematically evaluate the performance of a set of potential corridor-based improvements which are consistent with providing benefit by targeting specific transportation system deficiencies. These projects included the following strategies:

- Managed Lane Expansions and Conversions
- New Managed lanes
- Strategic capacity enhancement (new facilities)
- Expansion of general purpose capacity
- Conversion and upgrade of facility types
- Interchange modification and/or consolidation

A total of 41 candidate measures were evaluated. While representative of the overall set of new projects being considered, these 34 corridor alternatives should not be considered and exhaustive or exclusive list.

The performance evaluation for these projects was conducted using two approaches. To measure the benefits of capacity enhancement, the regional travel demand forecast model (the regional model) was used. Secondly, to measure the benefits of Active Traffic Management (ATM) strategies the ITS Deployment Analysis System (IDAS). This memo will describe how the regional model was used to evaluate capacity enhancements.

Initial Network Coding and Regional Model Execution:

The Council technical planning support staff coded 23 separate network scenarios for forecast years 2030 and 2060 that contained the 41 selected corridor projects. In addition, model runs were done for 2030 and 2060 for the no-build condition. Each no-build alternative model run was conducted, employing a feedback routine that assured a level of equilibrium between the demand and supply at the distribution and mode choice level. The person trip tables resulting from these model runs (for 2030 and 2060) were used as the basis for the build scenario model runs, which were subject to the mode choice model prior to assignment. Transit service levels (e.g., speeds, fares, headways) were not changed from the no-build for the build scenarios. Therefore, the resulting trip assignments do not reflect changes in transit service levels that may result from the proposed improvements. However, some changes in mode shares may be evident since the auto level of service will often change as a result of the alternatives' capacity enhancements. Finally, note that the 41 corridor projects were grouped within the 23 build scenario model networks in a way that avoided most of the affected travel flows from each alternative from overlapping. Projects were also grouped, where possible, by similar types of improvement categories (those categories listed above). Appendix A contains a series of selected-link assignments showing the extent of travel sheds and their potential overlap. For a full description of the modeling assumptions and methodology used for these initial model runs, see "MHSIS Modeling Methodology", a memo from the Council staff. The resulting model runs, and all associated files, were transmitted to the Parsons Brinckerhoff (PB) for performance measure evaluation.

Extraction of Performance Measures:

In order to evaluate the performance of each coded corridor project, it was necessary to isolate the travel shed for that corridor. This was done by tagging the corridor links themselves within the unloaded network, and using these tagged links to run a selected link assignment. New link attributes were added to the network which was specific to the corridor improvement. These were treated as indicator values, which normally defaulted to a value of "0" but took on a value of "1" for corridor links of that particular corridor ID. This was done for both the build and no-build networks for each hour of the day, as the standard assignment model includes them. In some cases, links that were very closely parallel to the subject corridor links, such as coded frontage roads, were also included as selected links for that corridor. The assignment model was re-run for each scenario and year, using the same assignment methodology but adding a selected link procedure for each corridor project within the scenario networks. A selected link option assignment uses the standard regional model assignment algorithm, but adds a feature that essentially tracks any trip that uses any link that is in the specified selected set. The selected link assignment also included a selected trip table as well as link attributes that were specific to the selected corridor links.

Using this approach, which was also applied to the no-build networks, we were able to develop a database of corridor-specific performance measures on a link and origin-destination trip basis. This allowed us to compute a variety of measures including:

- Vehicle-hours and Vehicle Miles of Travel (VHT and VMT)
- Total trips involved in each corridor
- Delay on links, calculated as the difference in congested and uncongested VHT
- Mode share, from the selected OD trip tables

Each of these measures could be summarized by several different categories, including facility/lane type, Volume/Capacity ratio, trip length and/or time of day. Mode share was computed by filtering the regional person-trip tables by the presence of trips in the selected link trip tables, and summarizing the corridor person-trips by mode.

Note that the effectiveness of this methodology to isolate specific project impacts depends upon the degree to which the travel sheds of the projects within each scenario network are in fact separate and distinct. This is largely true of most corridor projects tested, except for two groups of intersection consolidations on I494 and I35E which should be considered as a unit since their travel sheds are identical.

Technical Procedures:

The previous section describes the general methodology used to estimate the performance indicators for individual corridor projects. This section describes the particular modeling steps, and detailed procedures used to execute this methodology.

Transit Network Tagging:

The selected link assignment required that each corridor link in the appropriate scenario networks be tagged, so that these links could be easily identified. The following link ID's were added

Scenario 1:	I30B, I35B, I36B, I39B, I44B	Scenario 13:	I8B, I9B, I11A, I12A, I13B
Scenario 2:	I32B, I43B	Scenario 14:	I27A
Scenario 3:	I14B, I33A	Scenario 15:	I28B
Scenario 4:	I1B, I6B, I26B	Scenario 16:	I22B
Scenario 5:	I17A, I19A	Scenario 50:	I50
Scenario 6:	I18A, I20B	Scenario 51:	I51
Scenario 7:	I21B, I23A	Scenario 52:	I52
Scenario 8:	I3A, I42B	Scenario 53:	I53
Scenario 9:	I4A, I45A	Scenario 54:	I54
Scenario 10:	I29B, I41A	Scenario 55:	I55
Scenario 11:	I10A	Scenario 56:	I56
Scenario 12:	I7B		

Figure 1 shows the physical location of these tags, which are set to 1 for the links involved with the corridor improvement. This was done for both no-build (all in the same network) and for the build alternatives, as appropriate for the scenario.

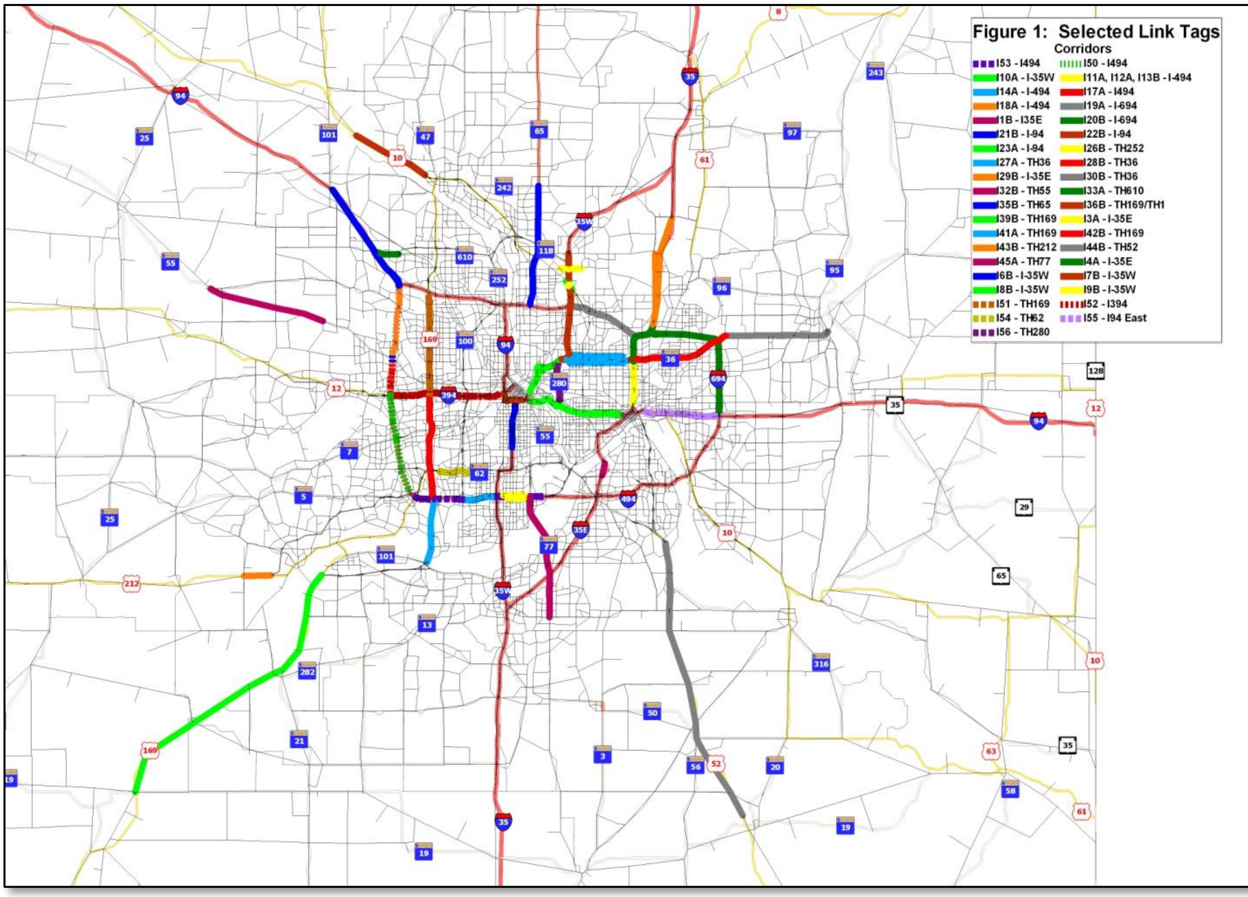


Figure 1: Selected Link Tags

Selected Link Assignments:

The mode-specific vehicle trip tables, containing SOV, HOV and truck trips, were assigned using the UPA assignment based toll procedure. This was the same script used by the Council staff for the initial assignments, except that the specific period's capacity was used instead of just the ampeak capacity, and the computation of volume to capacity ratio for each iteration was protected against links with zero capacity. In addition, a selected link designation was added, and both mode-specific selected link volumes and mode-specific selected link volumes were saved. All 24 hours were assigned and both build and no-build, year 2030 and 2060 scenarios were conducted. Appendix B contains an example of the script used for this selected link assignment, and a table and description of which selected link volume attributes are associated with which alternative and mode.

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Summary of VMT, VHT and Delay from Networks:

A procedure was next applied to read the build and no-build selected link loaded networks. The result was a comma-separated file that contains a database of VHT, VMT and Delay (in vehicle-hours) by hour, facility/lane type and volume to capacity range. These measures were computed based on the subset of links which contain more than 1 percent of the maximum selected link volume for a particular corridor. This was done to more realistically represent the effective travel shed. Appendix C contains an example script used to generate these databases. The procedure also saved a combined network that contains build and no-build volumes, selected link volumes, vht, vmt and delay measures for the travel sheds of each corridor alternative. The travel shed includes any link with a valid build or no-build selected link volume greater than 1 percent of the maximum selected link volume. The resulting spreadsheet is then summarized to present selected reports showing the change in performance measures for each corridor alternative.

Summary of Corridor Trips and Mode Share from:

The selected link assignments also produced selected link trip tables by hour and vehicle class. These selected link trip tables also included total selected vehicle trips in a separate table and file, and effectively defines the travel shed in a matrix (i.e., O-D) format. A CUBE/Voyager script was written to extract person-trips by mode from the corresponding mode choice output files, along with the loaded SOV and HOV time skims. These matrices, along with the actual selected link vehicle volumes, were consolidated to one file for each year/alternative/build-nobuild project. The tables include:

1 – Non-motorized person-trips
2 – Drive Alone person-trips
3 – 2-person auto person-trips (HOV plus non-hov)
4 – 3+ person Auto person-trips (HOV plus non-hov)
5 -- Transit person-trips
6 – Selected link vehicle trips
7 – SOV congested highway time
8 – HOV congested highway time

The last step in this script consolidated these values to AM Peak (model hour ids 7-9; 6:45am-9:45am) and PM peak (model hour ids 15-18; 2:30pm-6:00pm) and off-peak, which is the remaining hours. Daily totals were also computed. Travel times were computed using a weighted average of component hours based on the selected link vehicle trips, and person trips were allocated to periods also based on the relative hourly proportions from the selected link assignments. Note that the selected link vehicle trips were available by hour, where the person-trips were divided only into peak and off-peak periods.

A second script was developed to generate trip length frequency distributions from the resulting daily trip tables for auto and person-trips, which would be specific to the travel shed. Period-specific trip length frequency distributions could also be generated. These distributions, along with total trips and mode shares, were summarized in spreadsheets for each alternative, and compared with the corresponding no-build alternative.

Note that the selected link demand matrix did not exclude any non-zero trips interchanges; there was no artificial lower limit, as was used for the link-based analysis. Any absolute or percentage-based cutoff would result in considerable inconsistency between alternatives, since the magnitude of most OD demand is very dispersed. Also note that the usefulness of the mode share information as discussed here was limited since transit times were not adjusted to reflect possible improvements in service levels corresponding to the proposed improvements.

Appendix D contains an example of the matrix aggregation and trip length frequency scripts used in this analysis.

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Memorandum To: Project Files

From: Steve Ruegg, PB

Date: April 2, 2010 (DRAFT)

Subject: **MHSIS Travel Demand Forecasting Results**

Introduction:

This memorandum describes the key results from the travel demand forecasting analysis used to develop performance measures for transportation system improvements that were identified as a part of the Metropolitan Highway System Investment Study (MHSIS). The MHSIS was a study by the Metropolitan Council (the Council) and the Minnesota Department of Transportation (MnDOT) to develop a new approach to long term transportation investments for the Twin Cities Metropolitan area. This approach explicitly recognized that funding for transportation infrastructure will not be sufficient to eliminate or even reduce current congestion for the overall system for the foreseeable future. Given this, the challenge of the study was to change the way in which we evaluate and prioritize investments with the resources we do have available to maximize cost effectiveness in the broadest terms.

A key part of this study was to systematically evaluate the performance of a set of potential corridor-based improvements which are consistent with providing benefit by targeting specific transportation system deficiencies. These projects included the following strategies:

- Managed Lane Expansions and Conversions
- New Managed lanes
- Strategic capacity enhancement (new facilities)
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A total of 41 candidate corridor alternatives were evaluated. While representative of the overall set of new projects being considered, these 41 corridor alternatives should not be considered and exhaustive or exclusive list.

The performance evaluation for these projects was conducted using two approaches. To measure the benefits of capacity enhancement, the regional travel demand forecast model (the regional model) was used. Secondly, to measure the benefits of Active Traffic Management (ATM) strategies the ITS Deployment Analysis System (IDAS). This memorandum will describe the results of the regional model analysis. A detailed description of the methodology used for this analysis may be found in the March 15, 2010 memorandum entitled "MHSIS Travel Demand Forecasting Evaluation Methodology".

Travel Time Reliability:

Positive findings for improvements in travel time reliability are largely correlated with congested facilities and peak periods. As such, the reliability measure would best be examined as change in delay hours, separated by lane type (managed lane vs. general purpose lane). As the managed lane conditions will be congestion-free, then the real comparison points will be: 1) between build / no-build conditions in the general purpose lanes, and, 2) vehicular delay differences between managed lane / general purpose lanes. Appropriate measures of effectiveness will be vehicle minutes of delay by trip categorized by facility type. Peak period separation may accentuate the differences.

Figure 1: Reliability: 2030 Vehicle-Minutes of Delay Reduced Per Trip

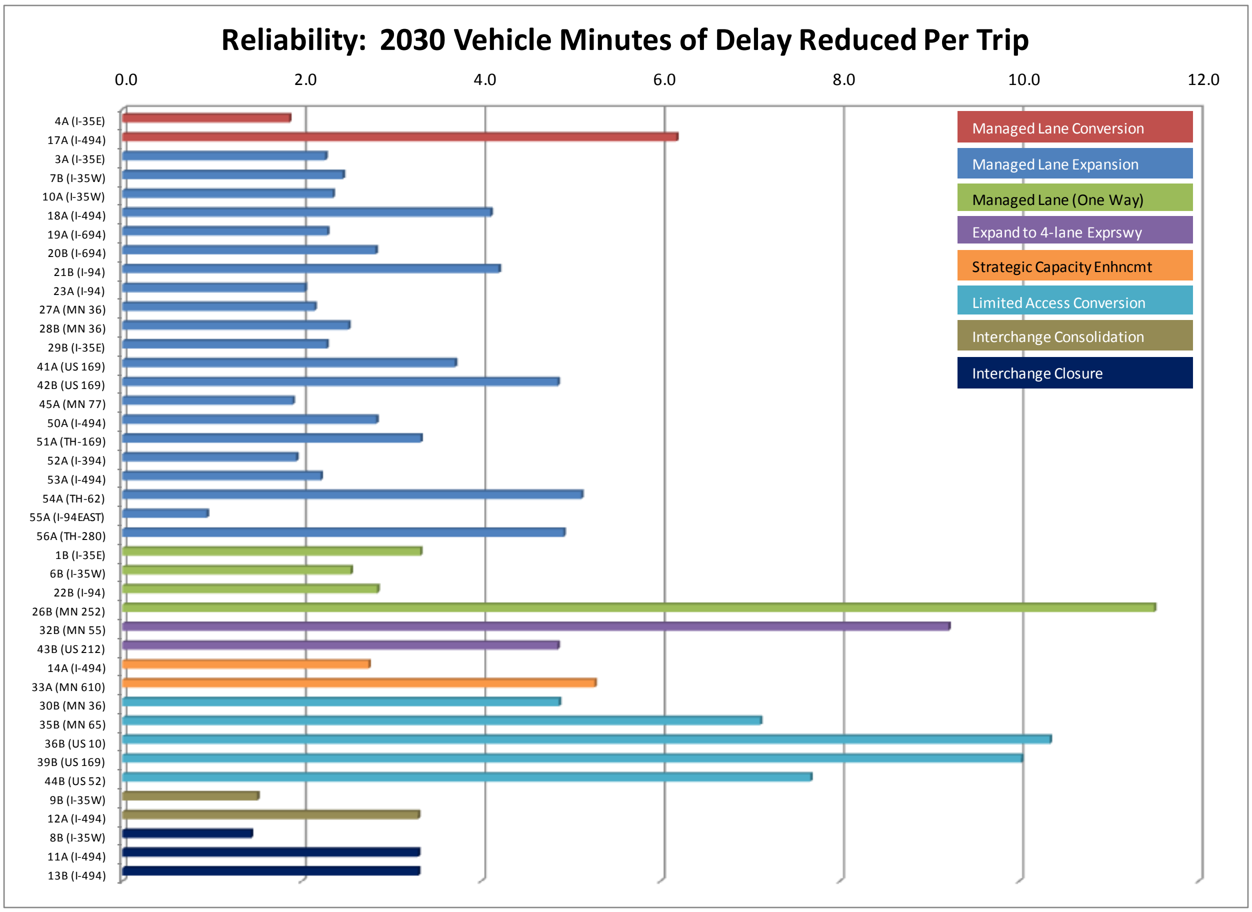


Figure 2: 2060 Vehicle Minutes of Delay Reduced per Trip

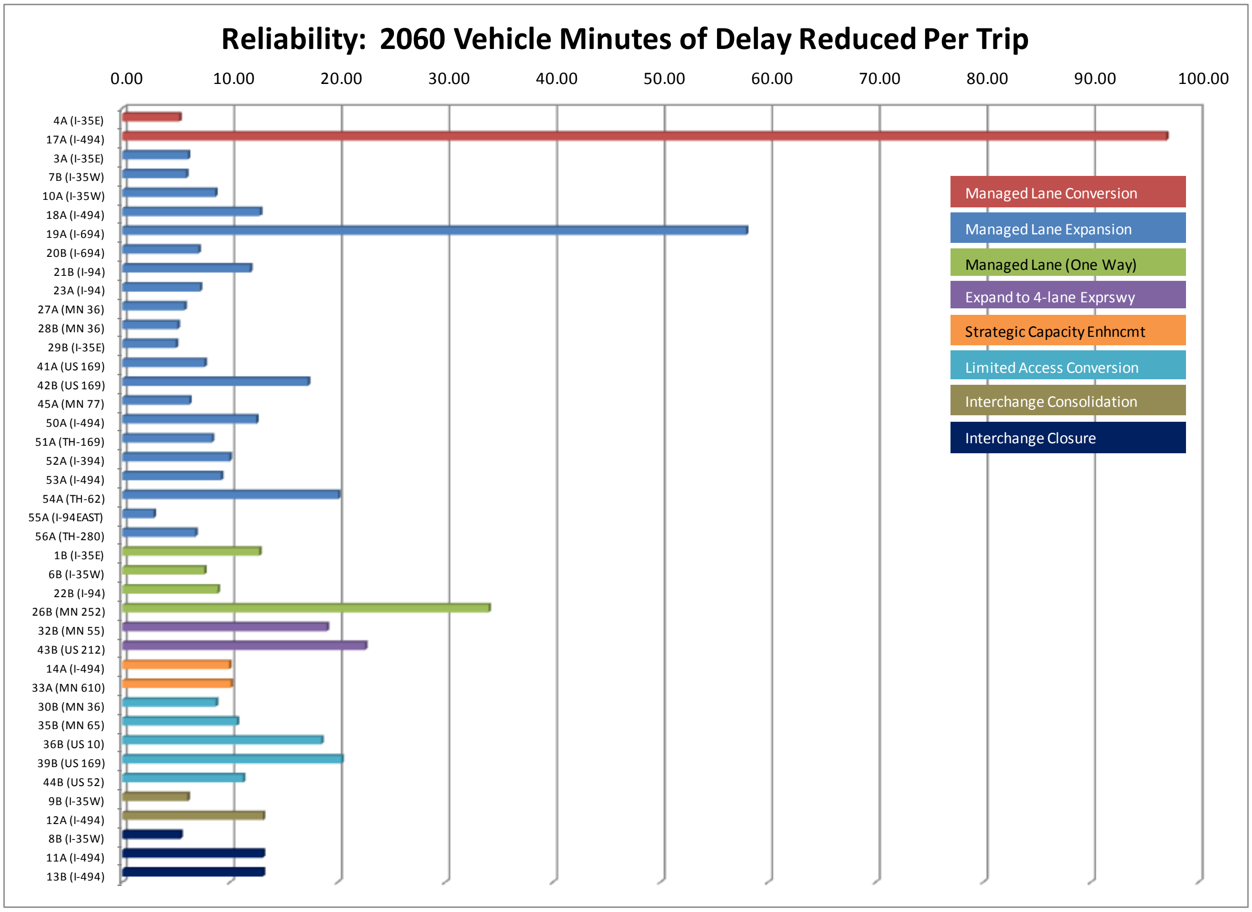


Figure 3: Reliability: 2030 Delay Reduction as a Percent of Total VHD

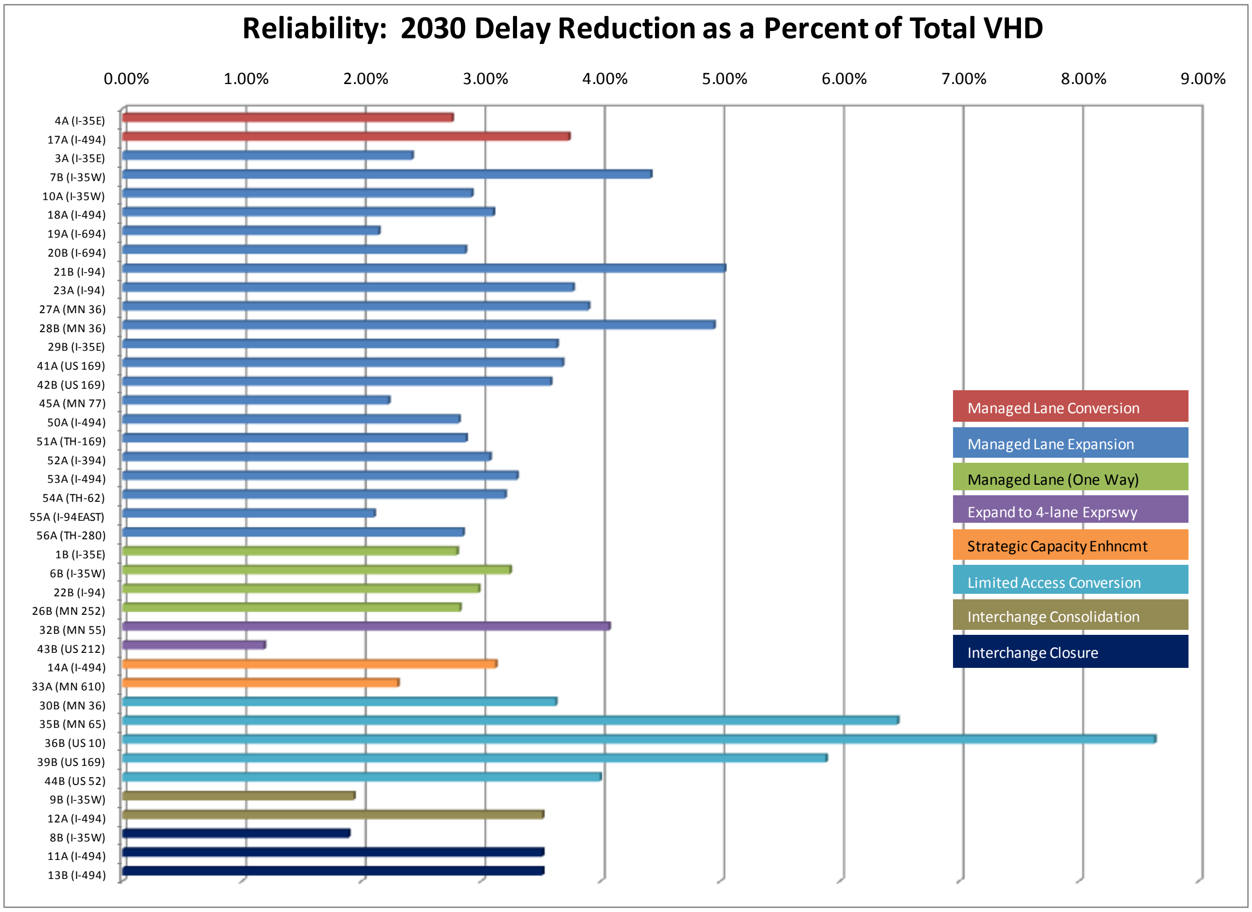


Figure 4: Reliability: 2060 Delay Reduction as a Percent of Total VHD (No-Build)

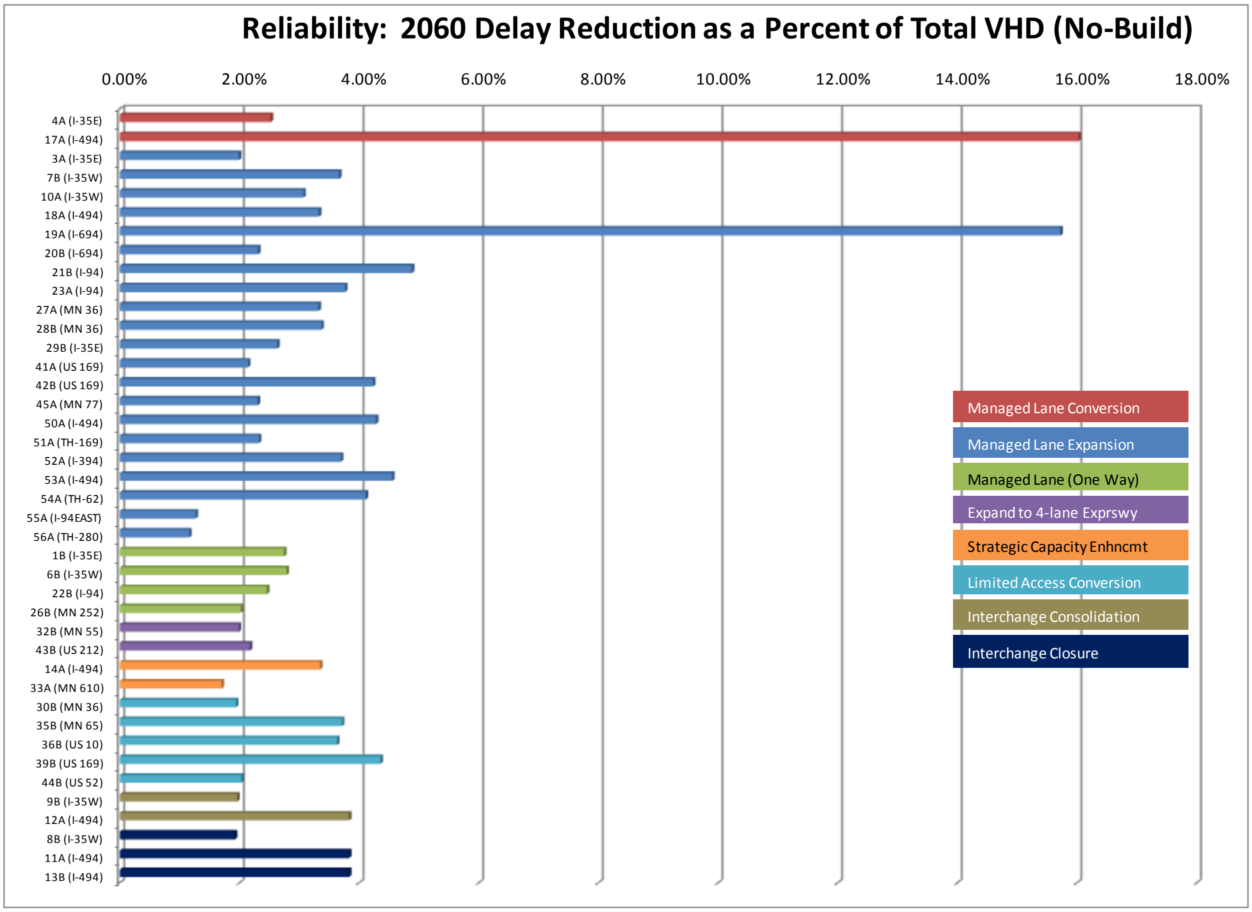


Figure 5: Reliability: Year 2030 Peak Delay Saved Per Trip (min/Trip)

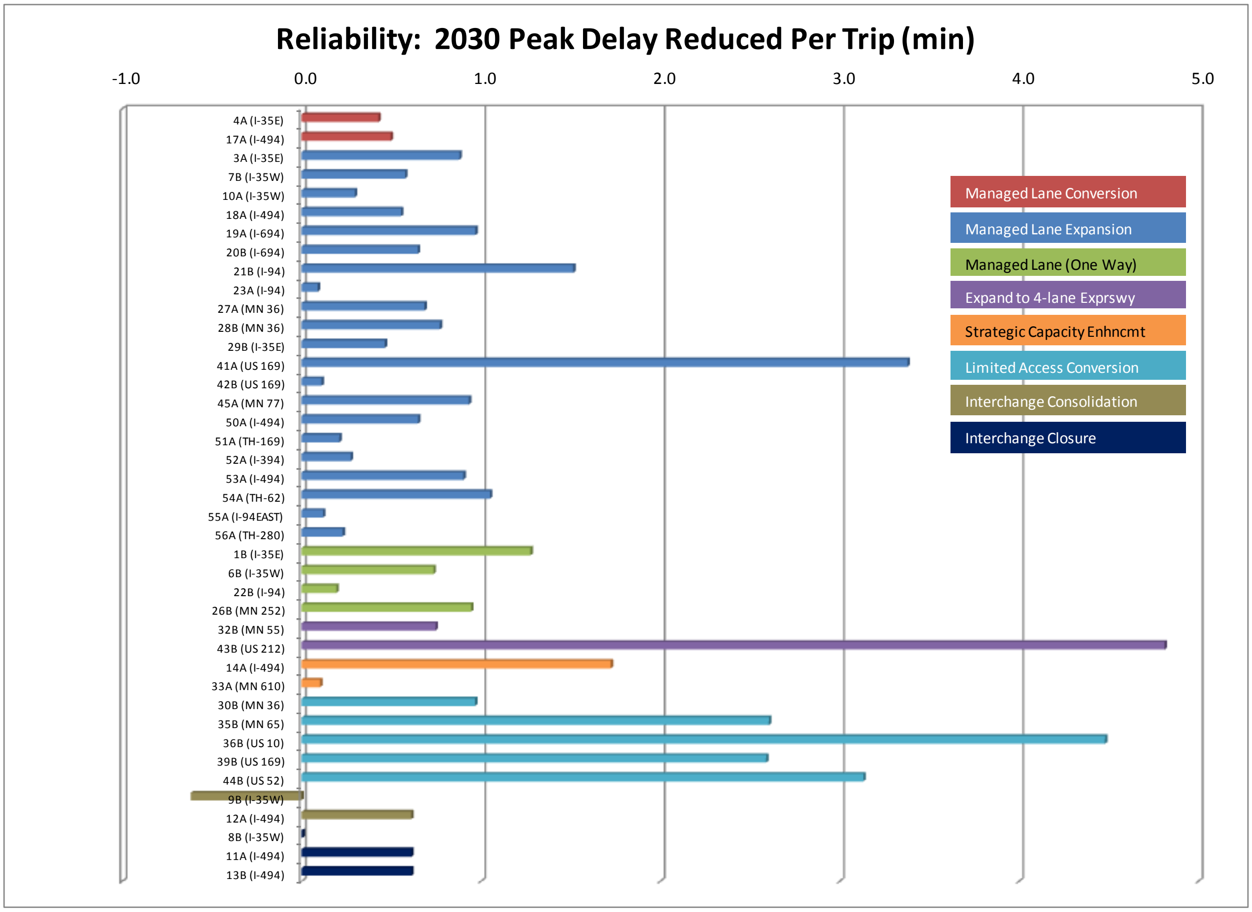
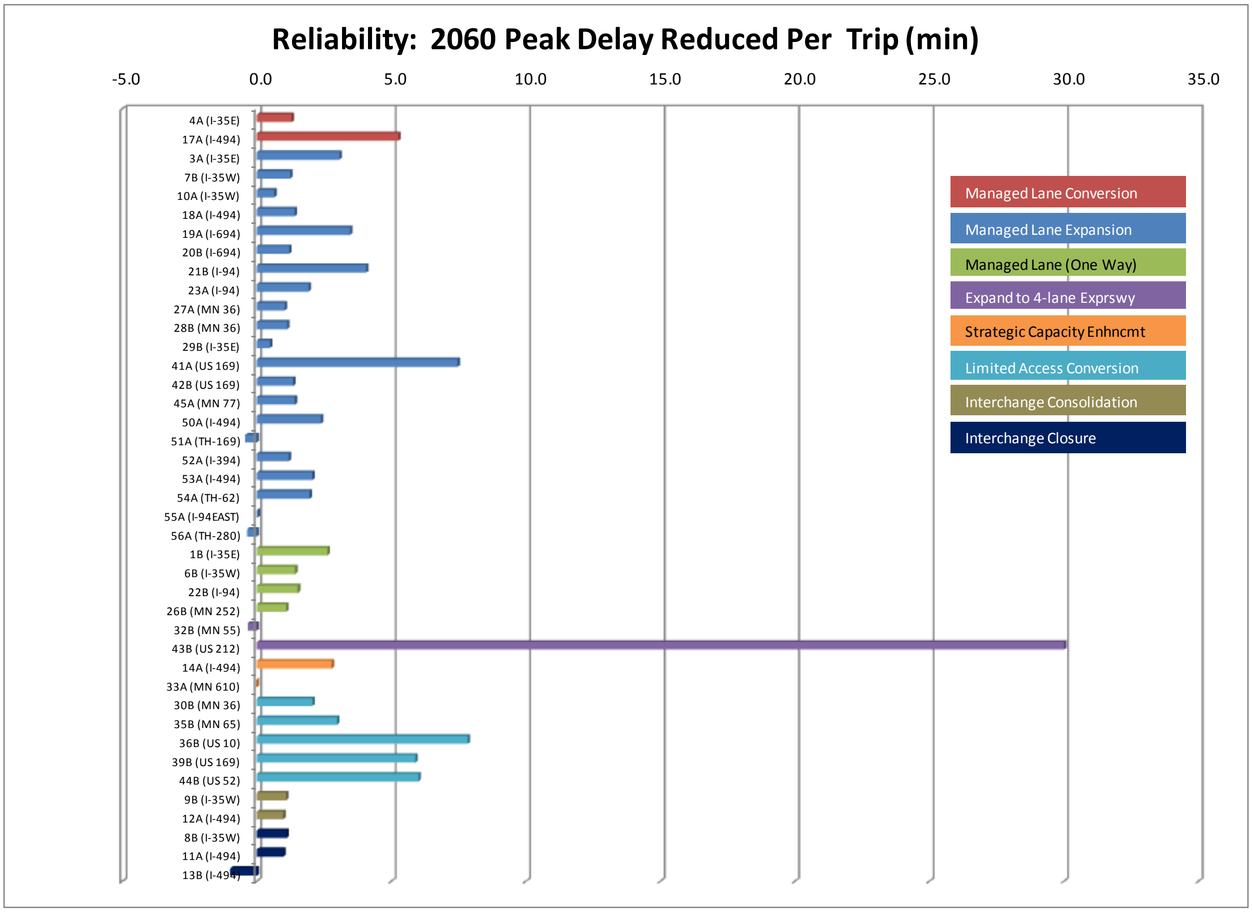


Figure 6: Reliability: Year 2060 Peak Delay Saved Per Trip (min/trip)



Throughput:

As the travel demand model held regional vehicular tripmaking static, the measures of effectiveness for person throughput in the model results only reflect how much the project expands the spatial market it is serving. An expansion of one market by the project yields a contraction of another market (e.g., I-494 drawing more vehicles from US 169, not necessarily serving more people in aggregate). So, this measure provides a perspective on the size of the market affected by the project. When calculated as person throughput per lane mile (directional centerline), the effect is to evaluate how many travelers are potentially served by the project. The greater the service per mile, the greater the spatial scope of effectiveness.

Figure 7: 2030: New Vehicular Throughput by Lane Mile

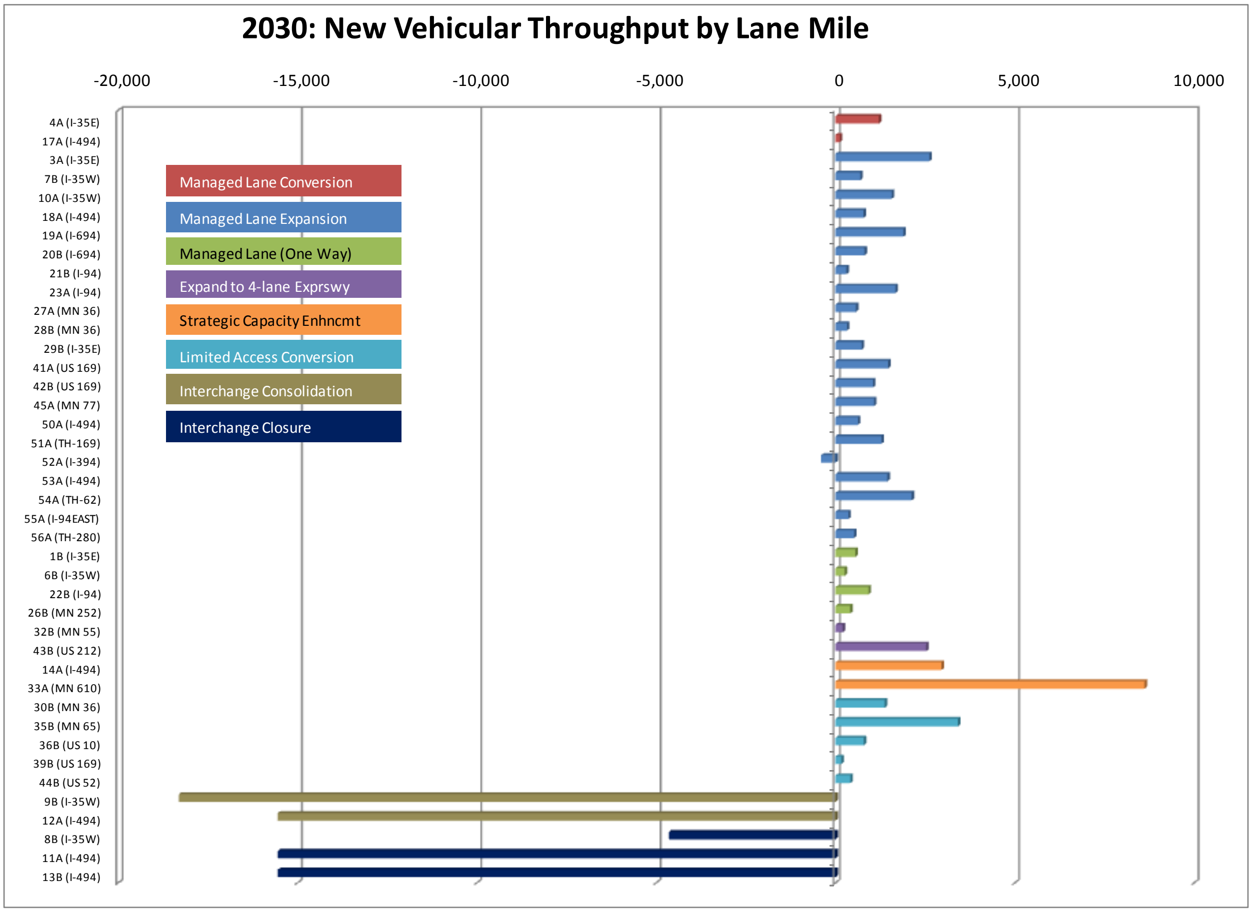


Figure 8: 2060: New Vehicular Throughput by Lane Mile

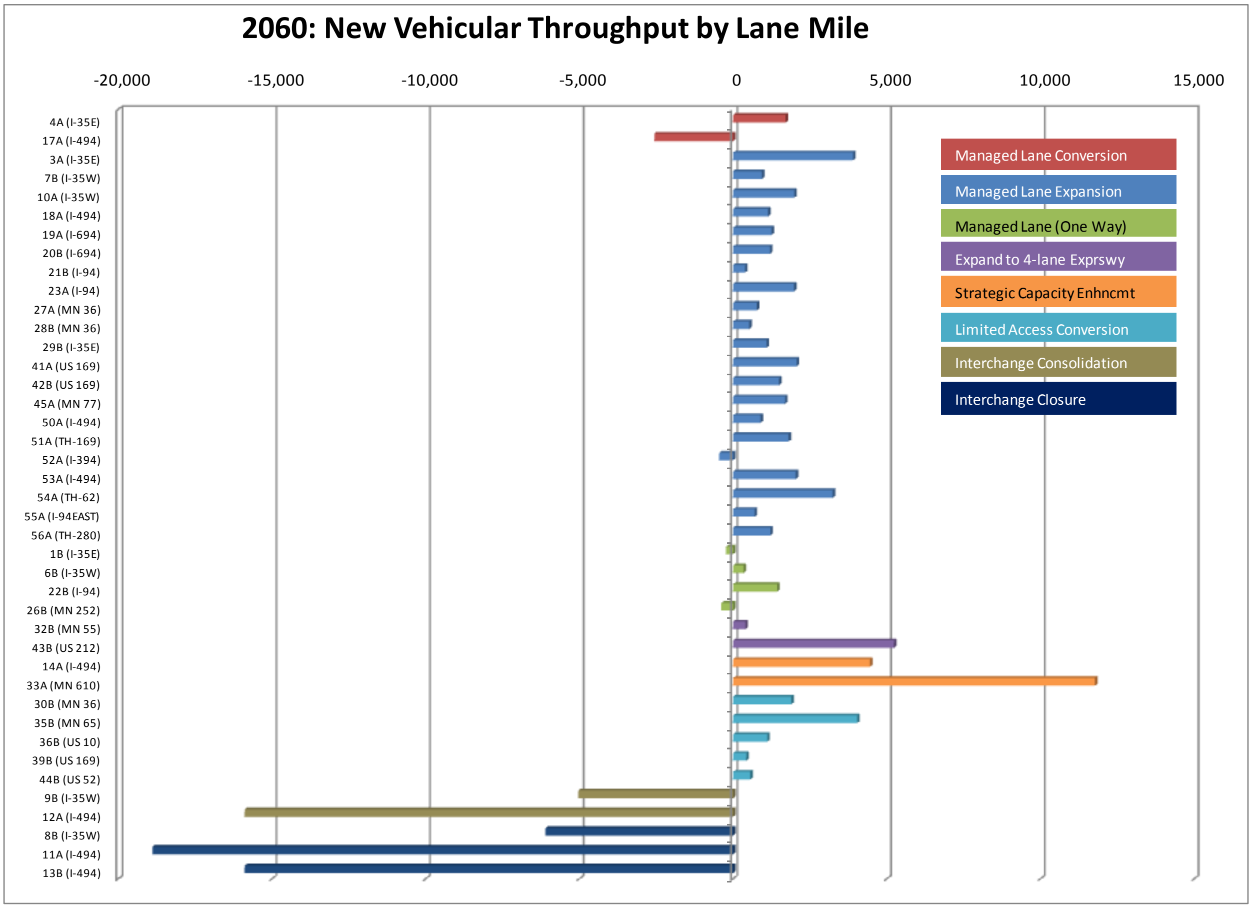


Figure 9: 2030: New Person Throughput by Lane Mile

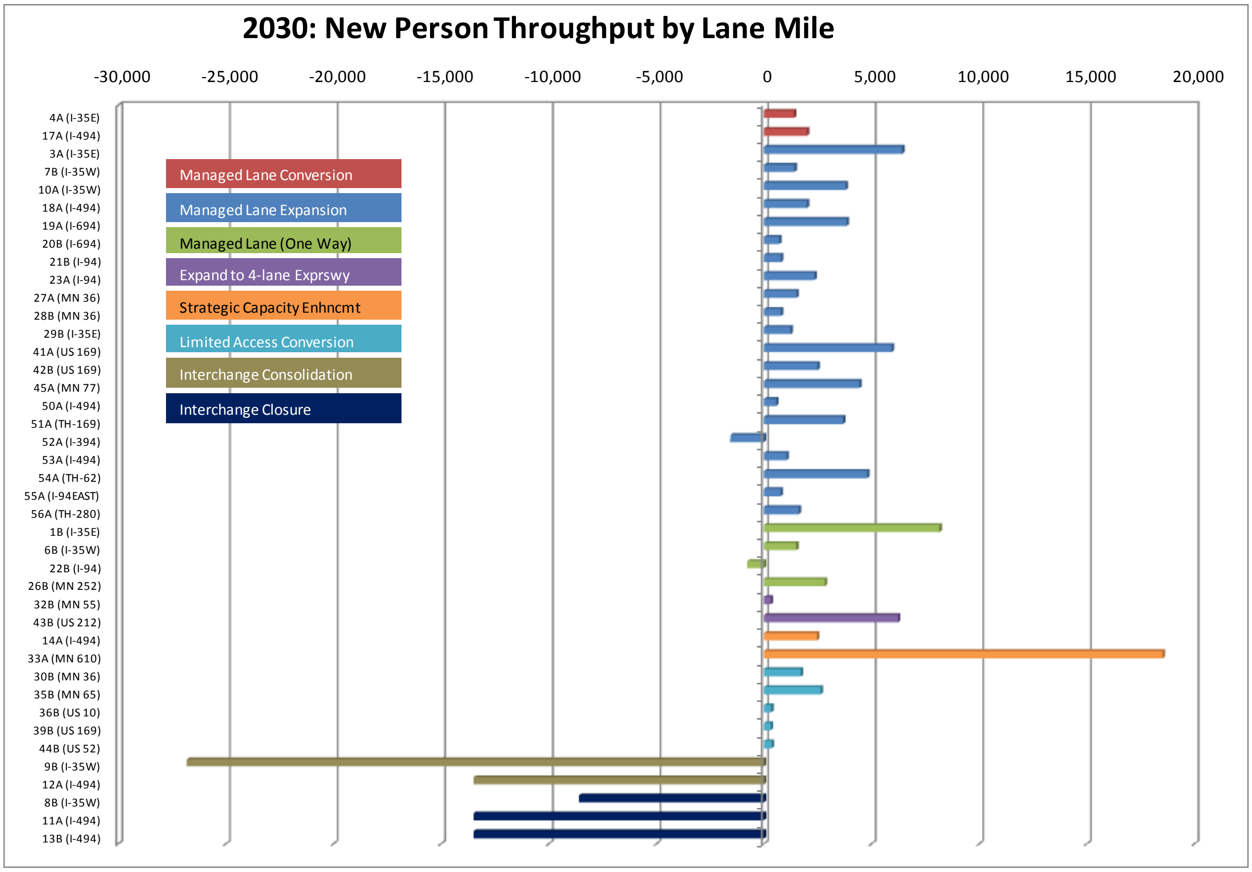
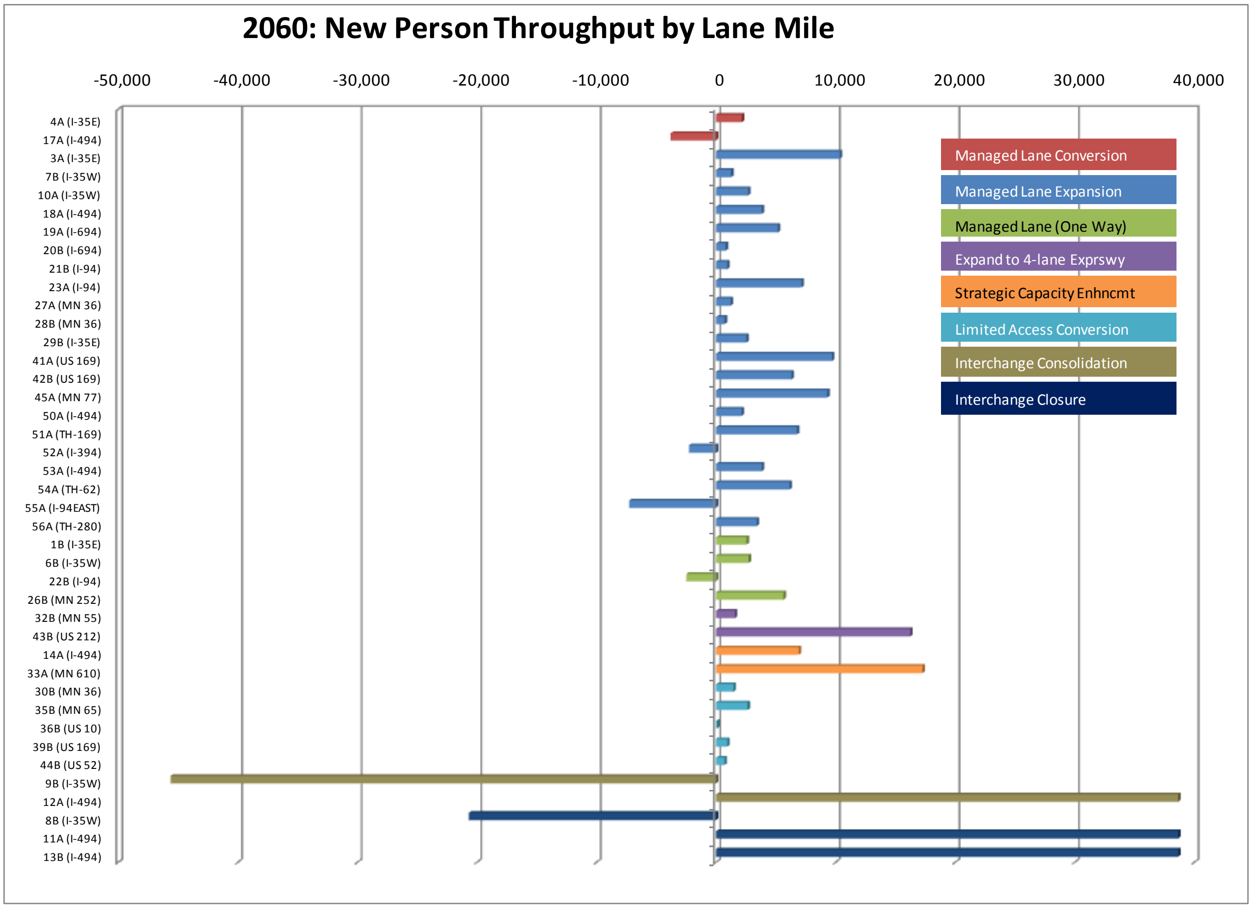


Figure 10: 2060: New Person Throughput by Lane Mile



Travel Time Reduction:

Examining the potential benefit/cost (as proxied by mileage normalization) that a project can provide for travel time reduction, vehicle hours of delay reduced per centerline mile will be used. This offers an easy-to-describe means of articulating benefits from the project.

Figure 11: 2030: Vehicle Hours of Delay Reduced by Lane Mile

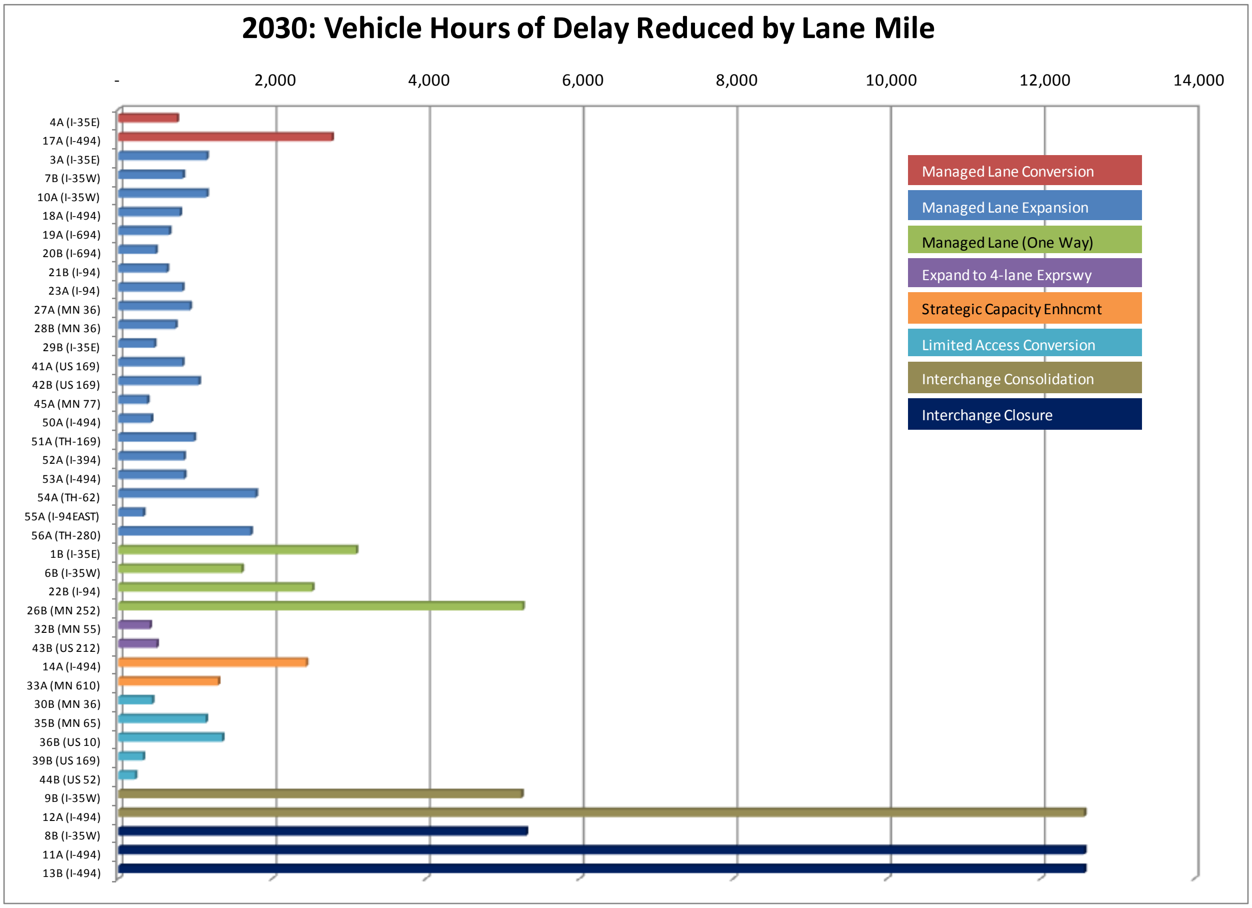


Figure 12: 2060: Vehicle Hours of Delay Reduced by Lane Mile

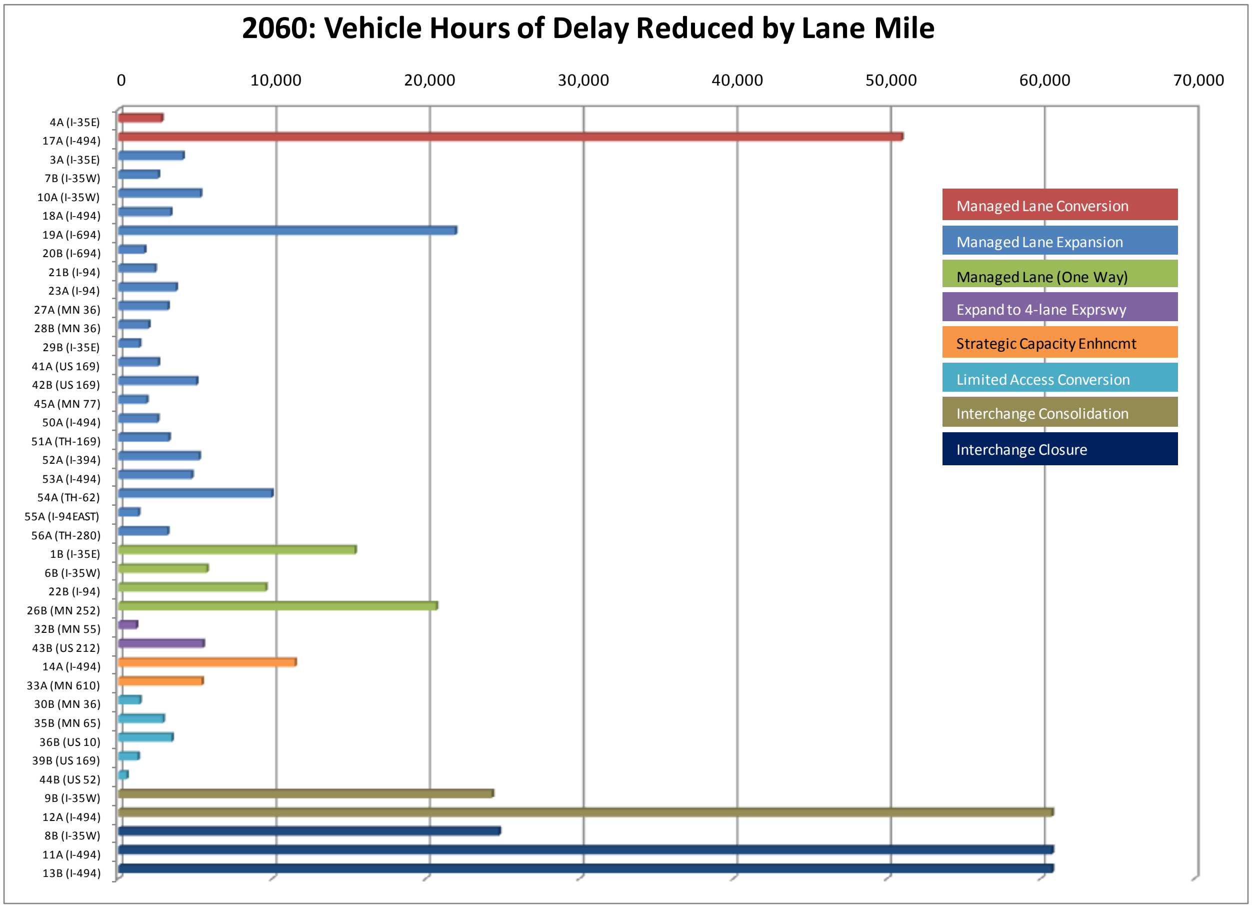


Figure 13: 2030: Change in Average Trip Time (Minutes Reduced)

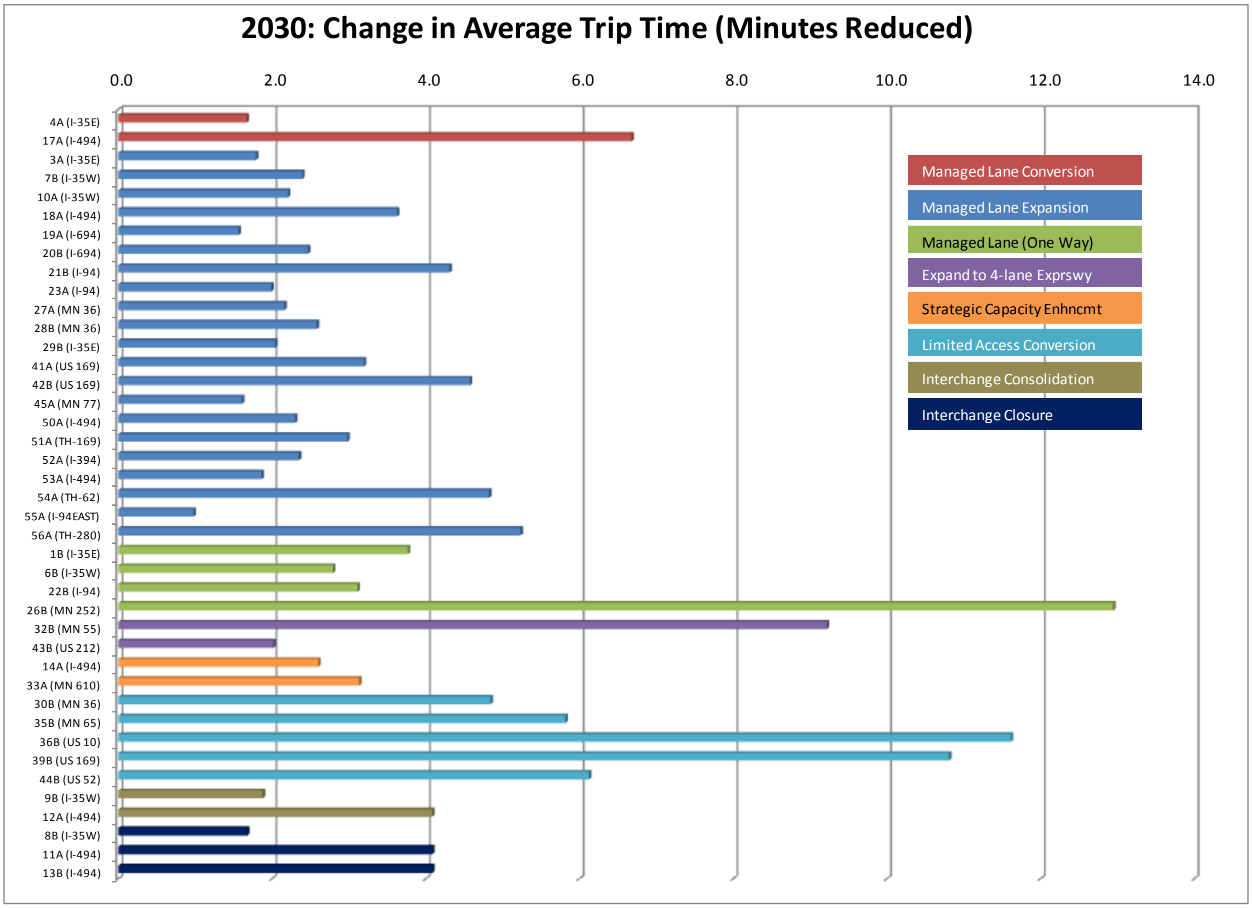
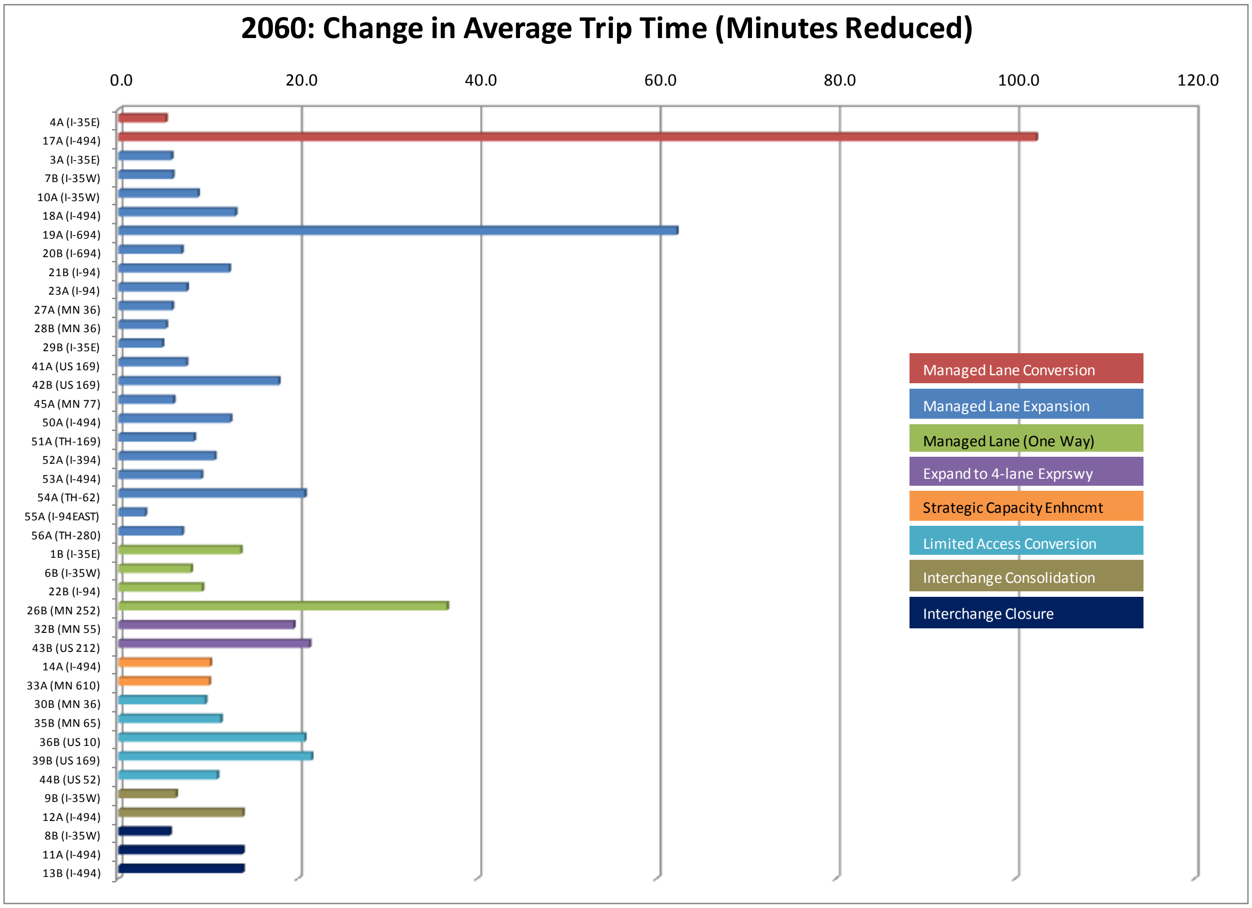


Figure 14: 2060: Change in Average Trip Time (Minutes Reduced)



Change in Congested VMT:

This performance measure is unscaled, which provides a measure of the total magnitude of the intended improvement and examines (throughout the network) how many sections of roadway are relieved by the project.

Figure 15: 2030: Reduction in Congested VMT

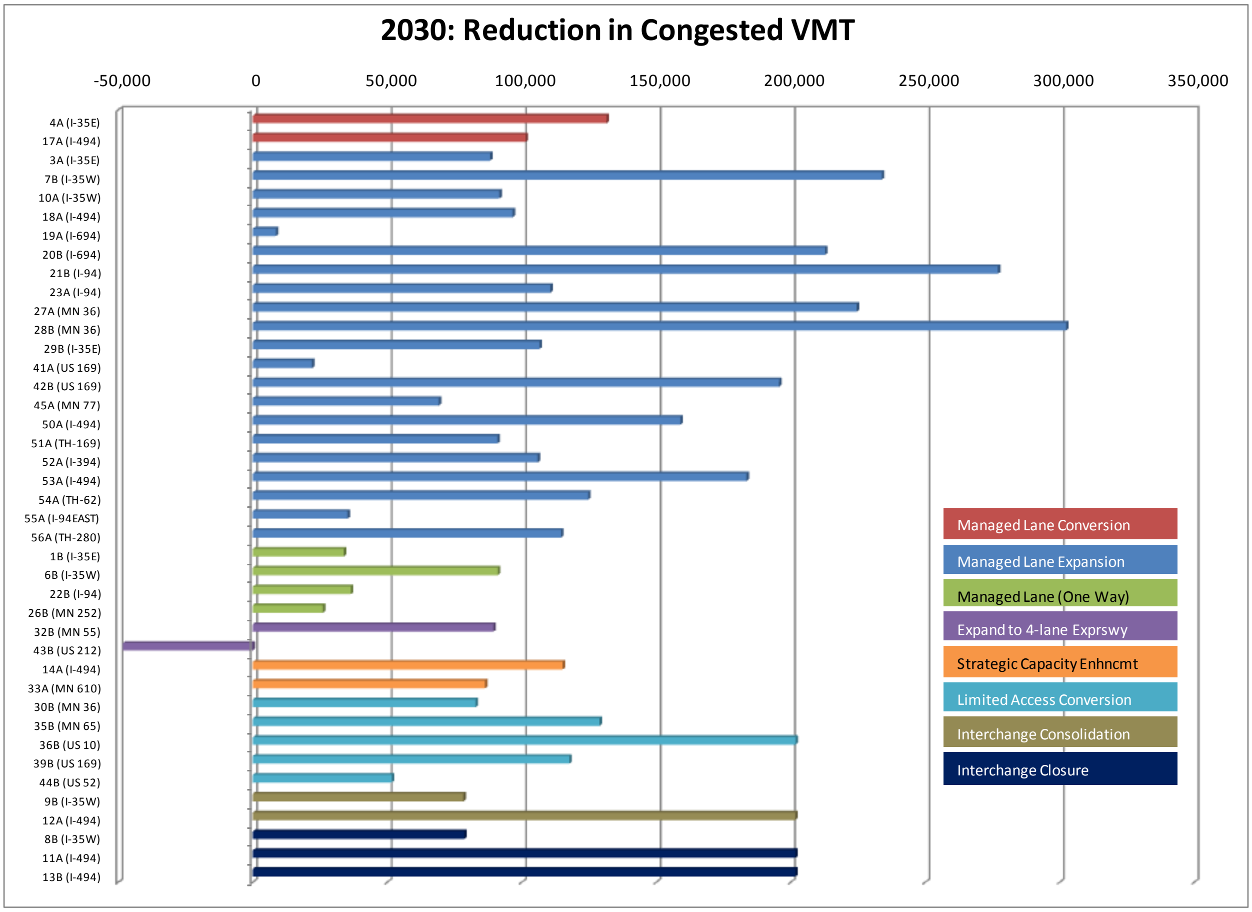
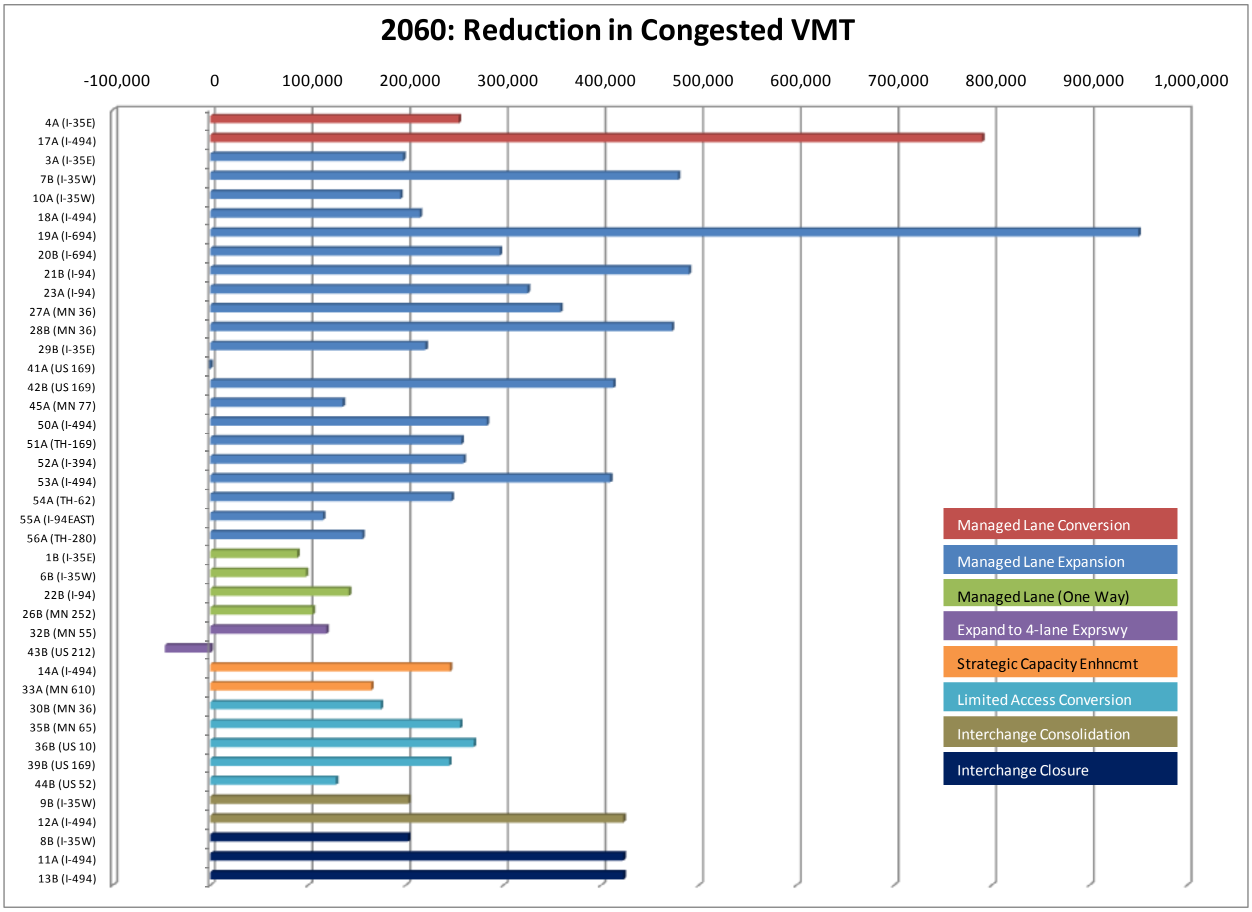


Figure 16: 2060: Reduction in Congested VMT

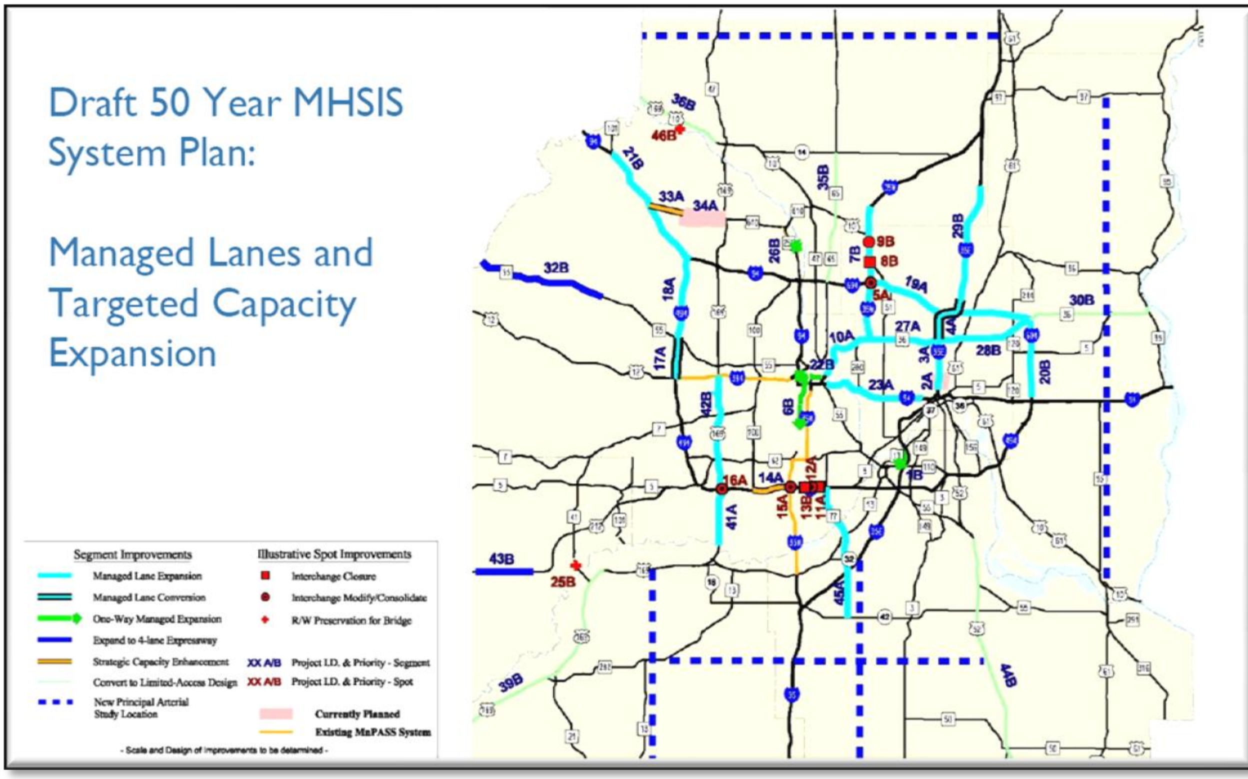


Appendix A:
Build Scenario/Corridor Project Correspondence and Travel Sheds

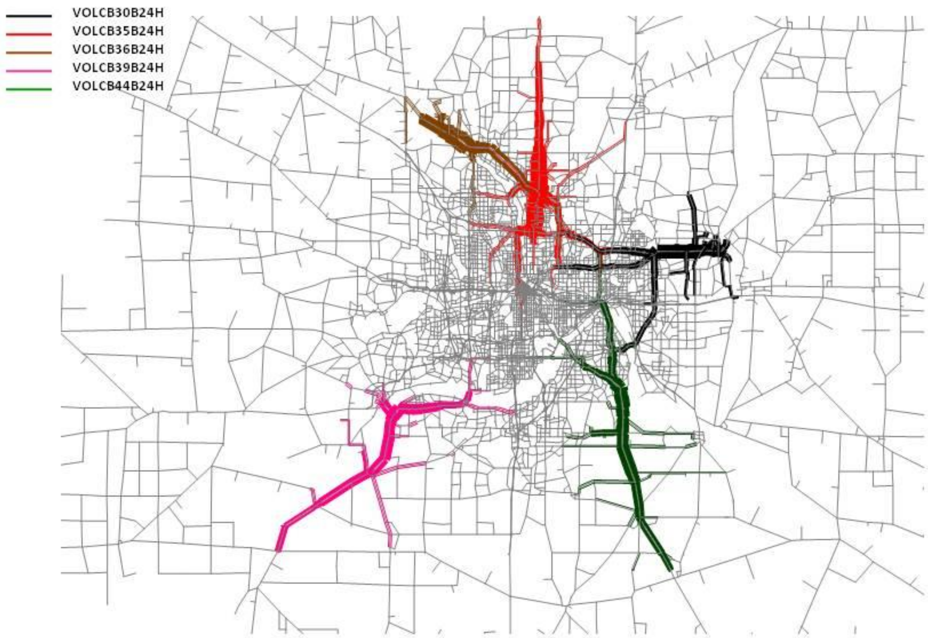
Table A-1: MHSIS Scenario/Project Correspondence

Scenario	Highways in Scenario	Project IDs
1	TH 36, TH 65, TH 169/TH10, TH 169, TH 52	30B, 35B, 36B, 39B, 44B
2	TH 55, TH 212	32B, 43B
3	I-494, TH 610	14A, 33A
4	I-35E, I-35W, TH 252	1B, 6B, 26B
5	I-494, I-694	17A, 19A
6	I-494, I-694	18A, 20B, (includes project 17A)
7	I-94	21B, 23A (includes projects 17A and 18A)
8	I-35E, TH 169	3A, 42B (includes project 2A)
9	I-35E, TH 77	4A, 45A (includes projects 2A and 3A)
10	I-35E, TH 169	29B, 41A (includes projects 2A , 3A, and 4A)
11	I-35W	10A
12	I-35W	7B (includes project 10A)
13	I-35W, I-494	8B, 9B, 11A, 12A, 13B
14	TH 36	27A (includes project 10A)
15	TH 36	28B (includes project 10A and 27A)
16	I-94	22B
50	I-494	50A (includes 17A and 19A)
51	TH 169	51A
52	I-394	52A
53	I-494	53A (includes 14A and 16A)
54	TH 62	54A
55	I-94 East	55A
56	TH 280	56A

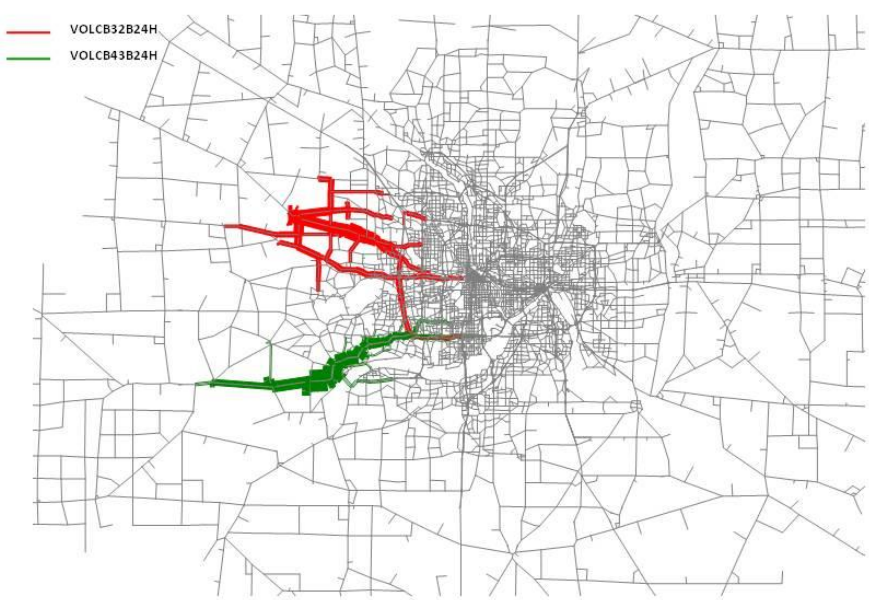
Figure A-1: Corridor Projects for Study



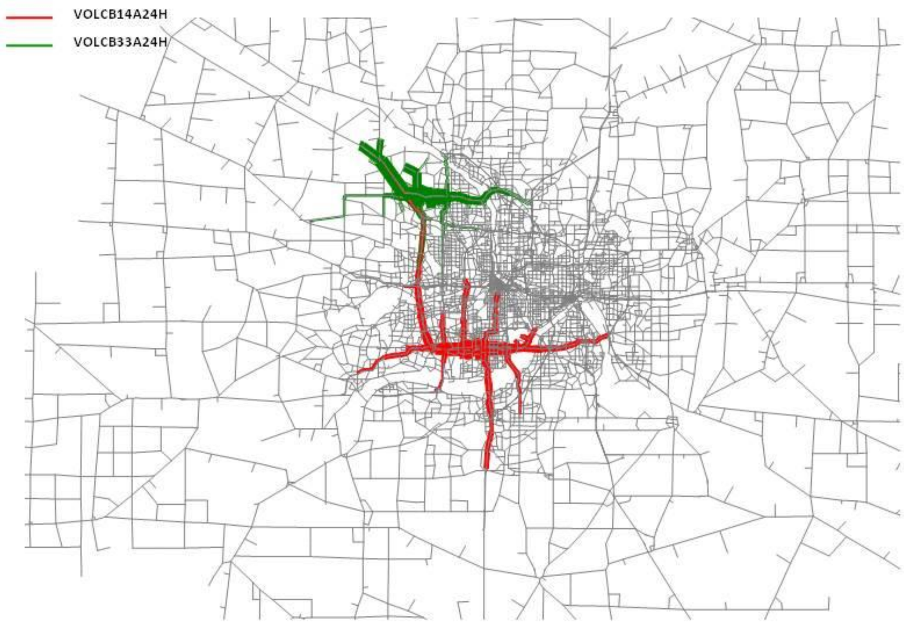
Year 2030 Travel Sheds for Projects Scenario 1: Alt 30B, 35B, 36B,39B and 44B



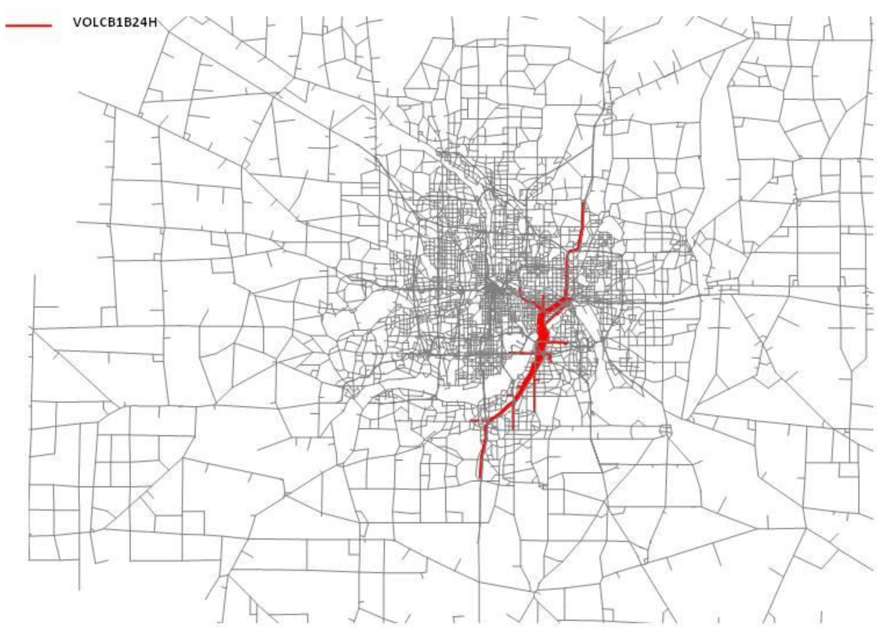
Year 2030 Travel Sheds for Projects Scenario 2: Alt 32B and 43B



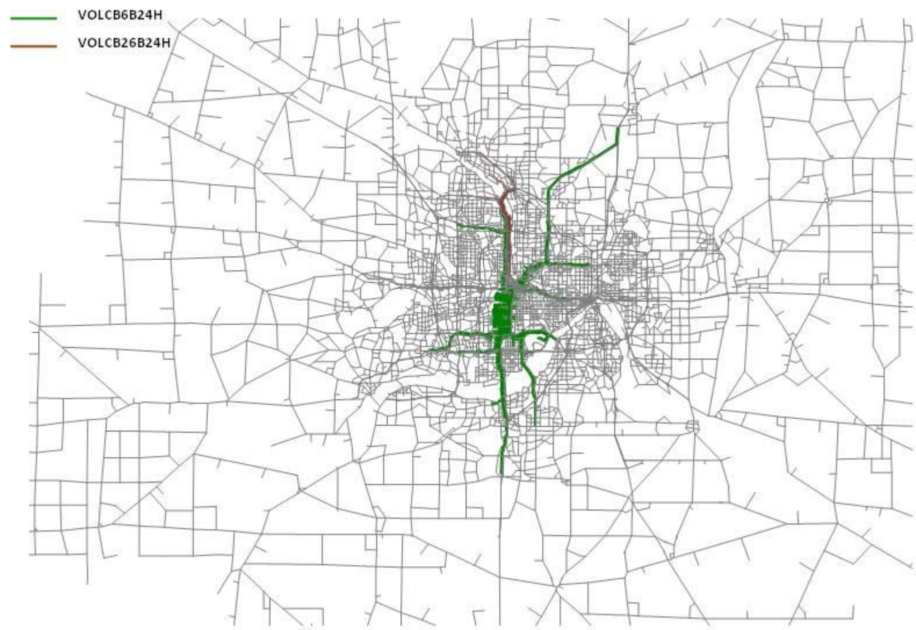
Year 2030 Travel Sheds for Projects Scenario 3: Alt 14A and 33A



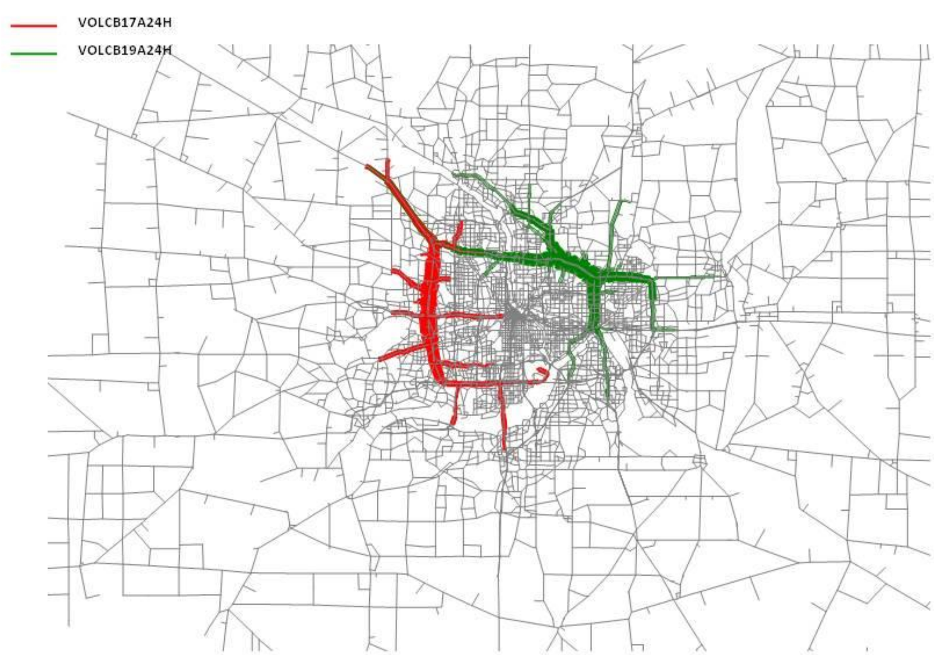
Year 2030 Travel Sheds for Projects Scenario 4: Alt 1B



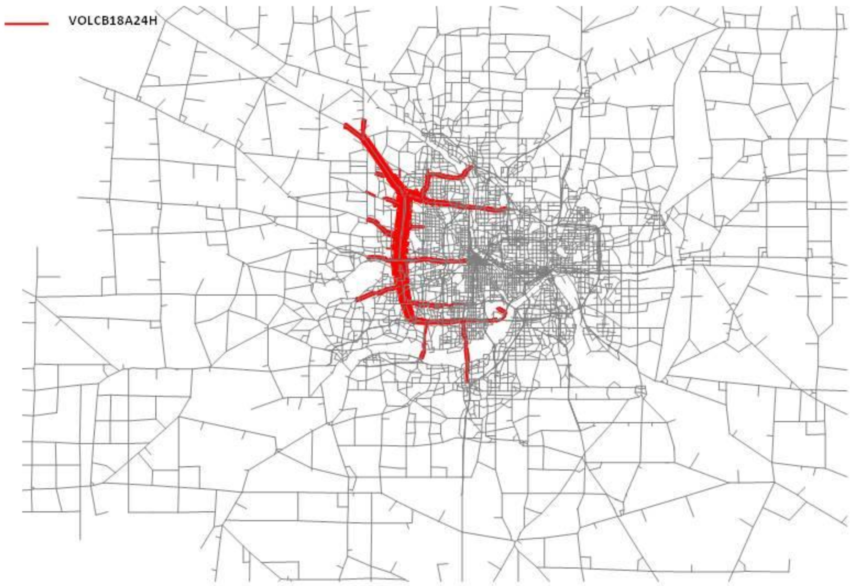
Year 2030 Travel Sheds for Projects Scenario 4B: Alt 6B and 26B



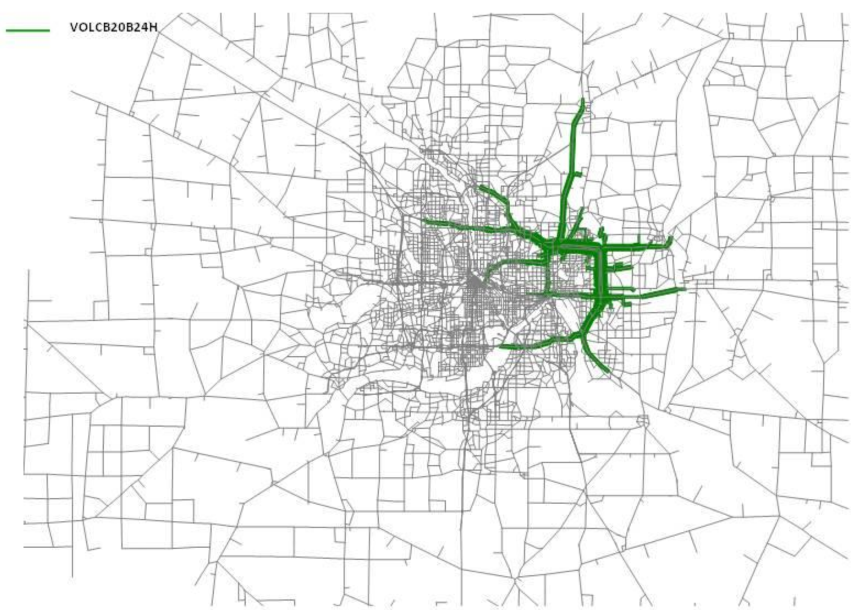
Year 2030 Travel Sheds for Projects Scenario 5: Alt 17A and 19A



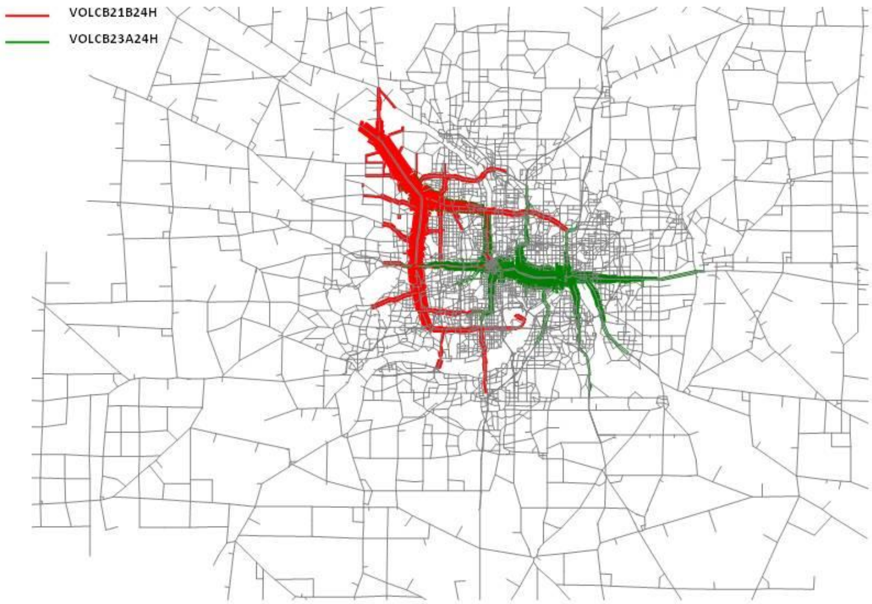
Year 2030 Travel Sheds for Projects Scenario 6A: Alt 18A



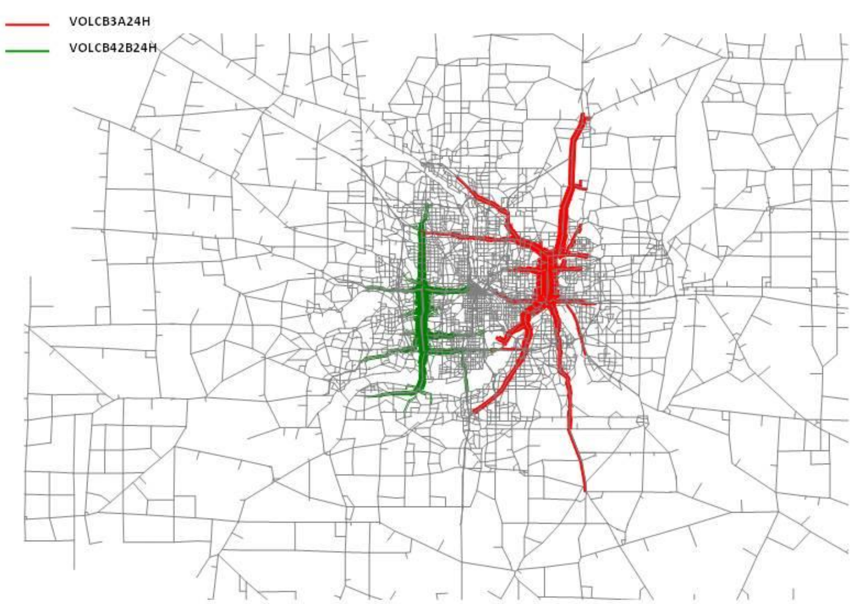
Year 2030 Travel Sheds for Projects Scenario 6B: Alt 20B



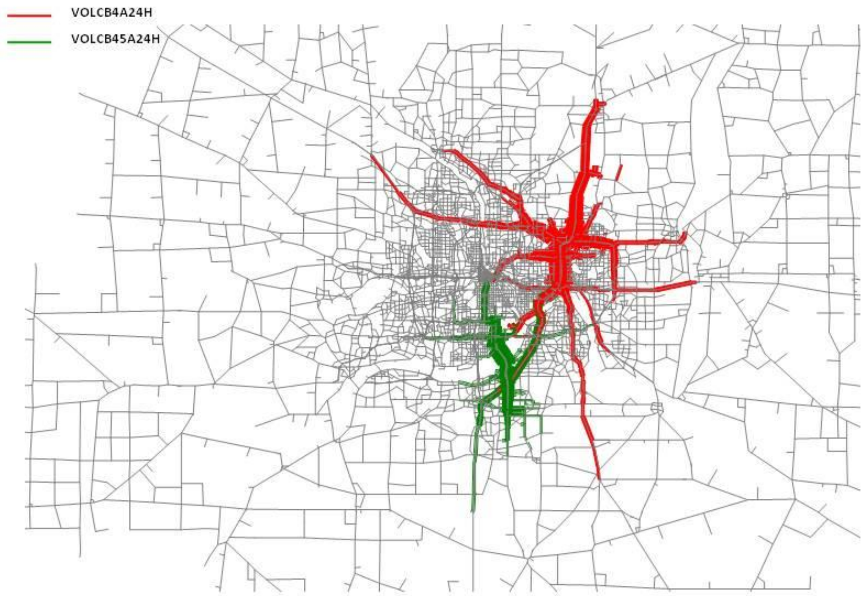
Year 2030 Travel Sheds for Projects Scenario 7: Alt 21B and 23A



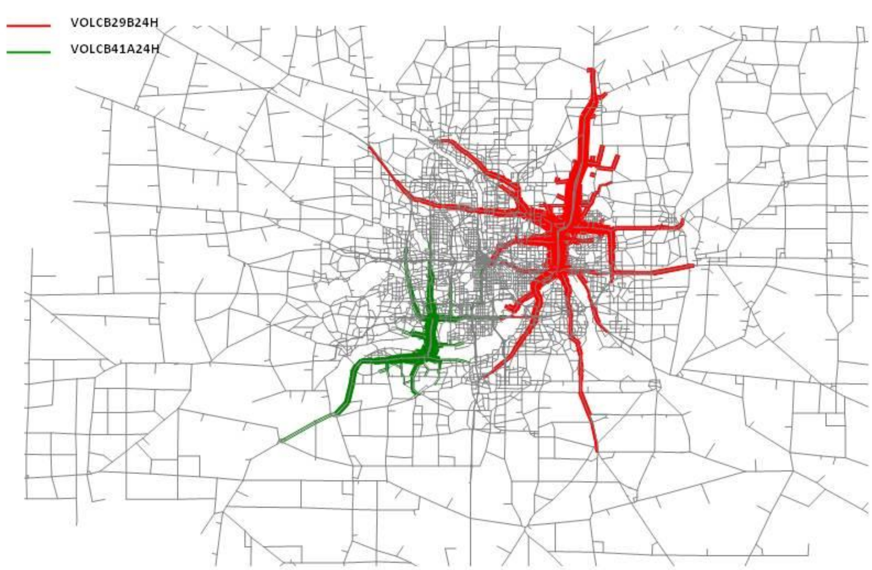
Year 2030 Travel Sheds for Projects Scenario 8: Alt 3A and 42B



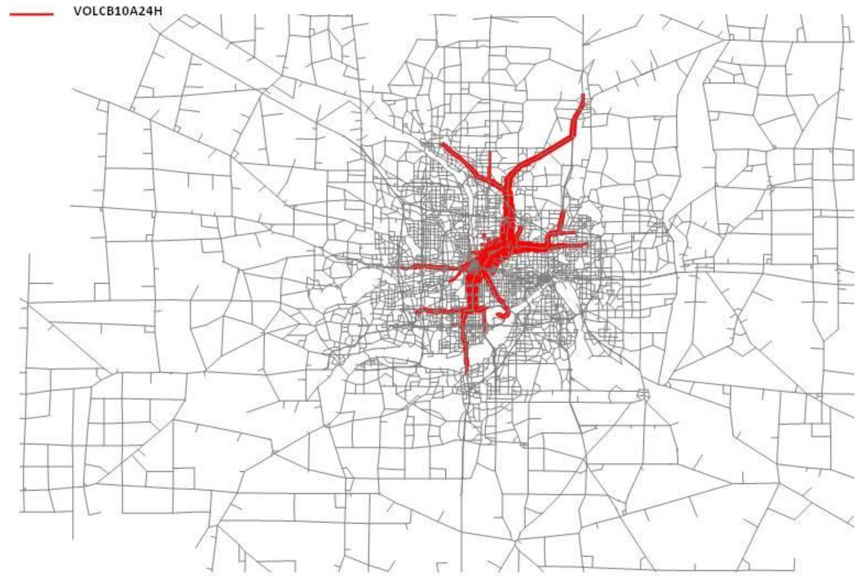
Year 2030 Travel Sheds for Projects Scenario 9: Alt 4A and 45A



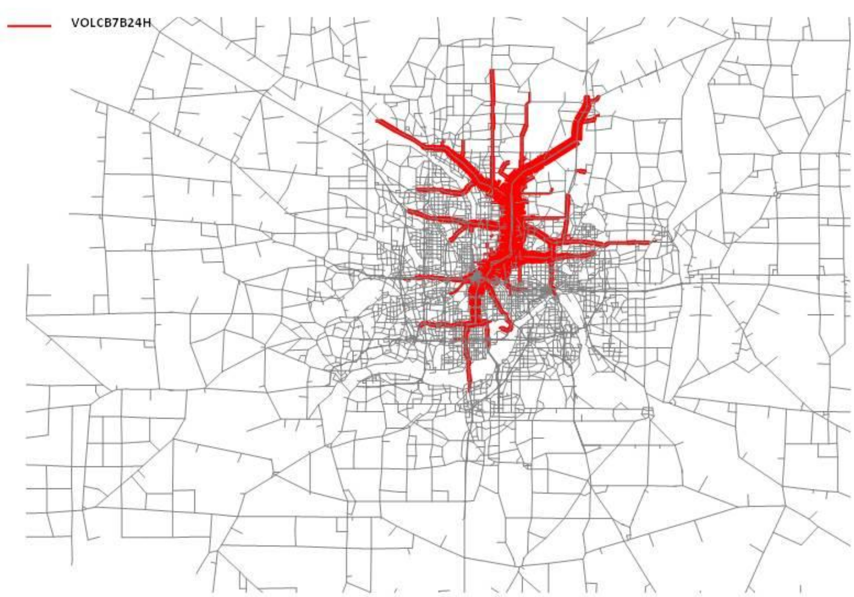
Year 2030 Travel Sheds for Projects Scenario 10: Alt 29B and 41A



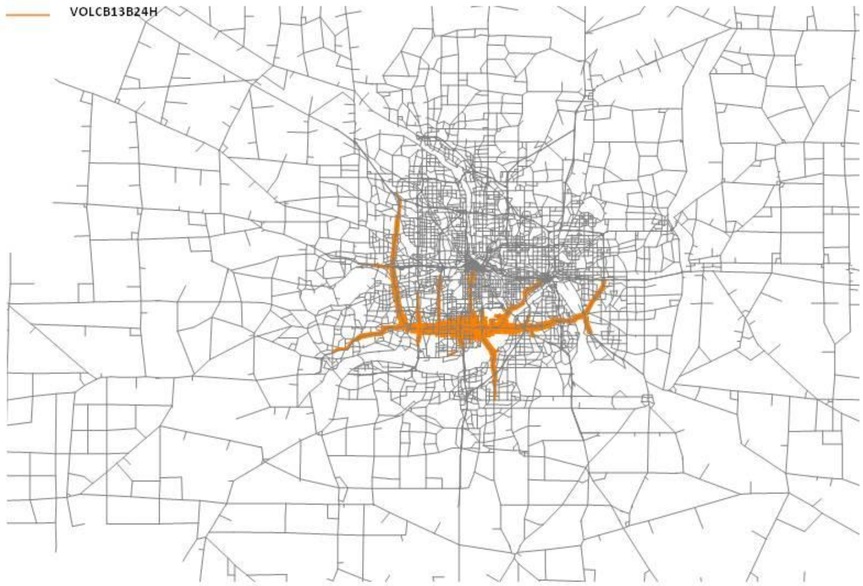
Year 2030 Travel Sheds for Projects Scenario 11: Alt 10A



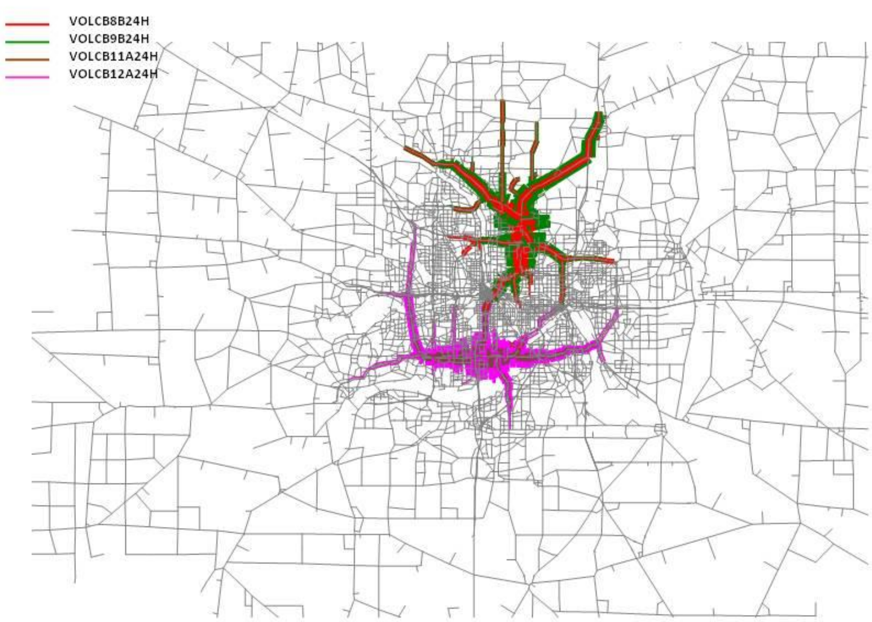
Year 2030 Travel Sheds for Projects Scenario 12: Alt 7B



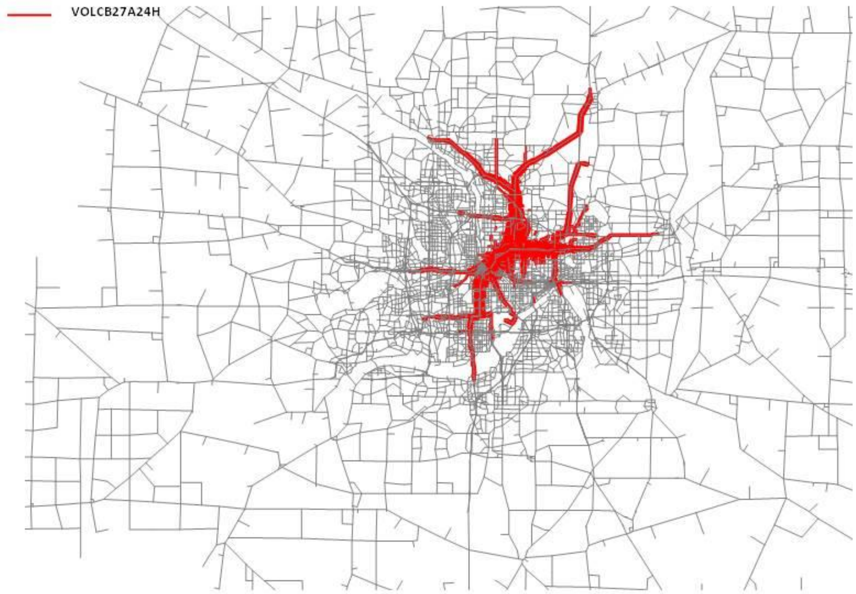
Year 2030 Travel Sheds for Projects Scenario 13B: Alt 13B



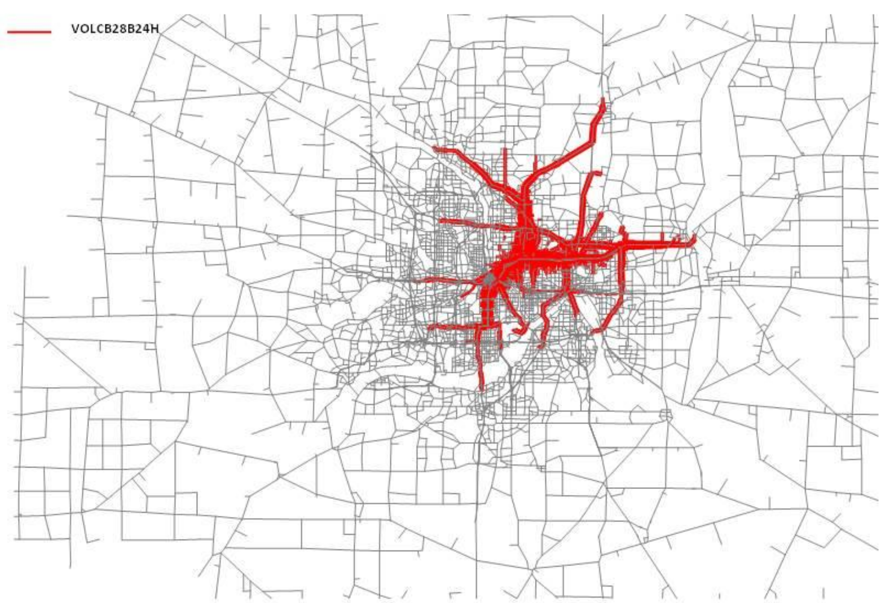
Year 2030 Travel Sheds for Projects Scenario 13: Alt 8B, 9B, 11A and 12A



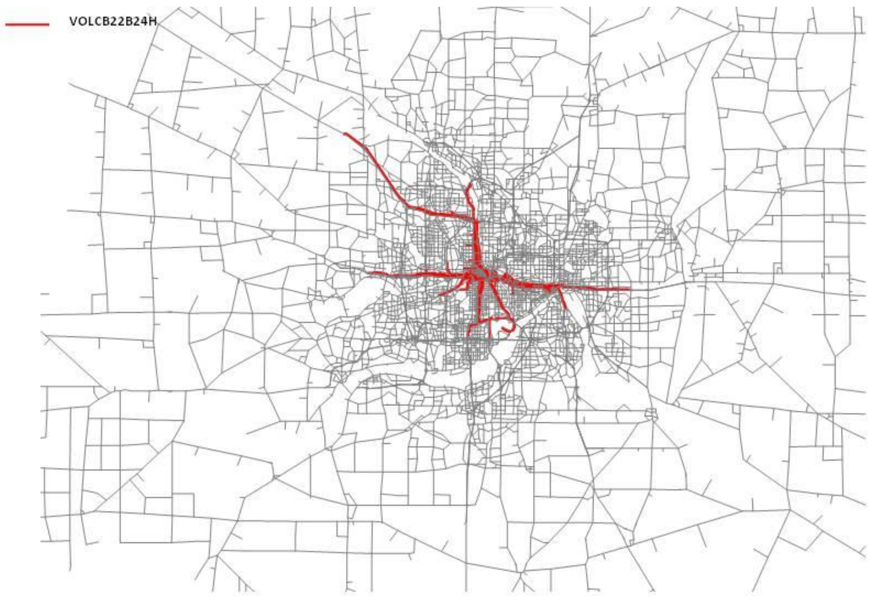
Year 2030 Travel Sheds for Projects Scenario 14: Alt 27A



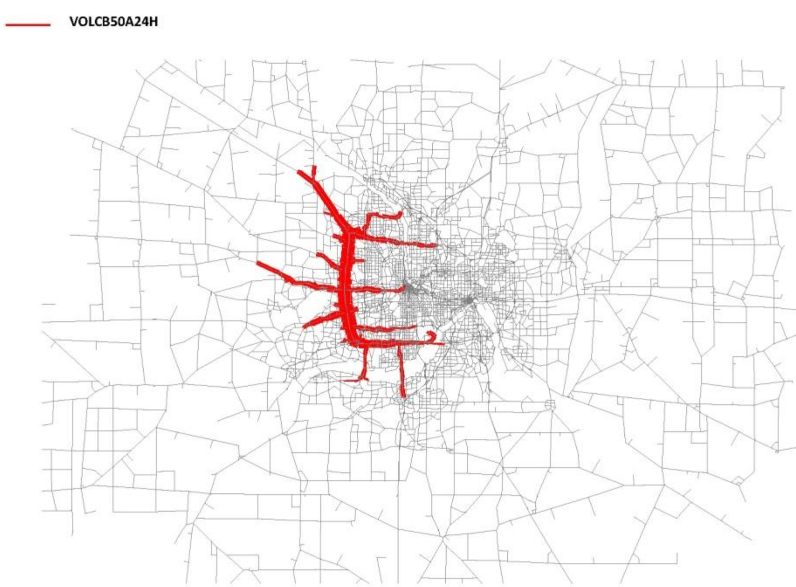
Year 2030 Travel Sheds for Projects Scenario 15: Alt 28B



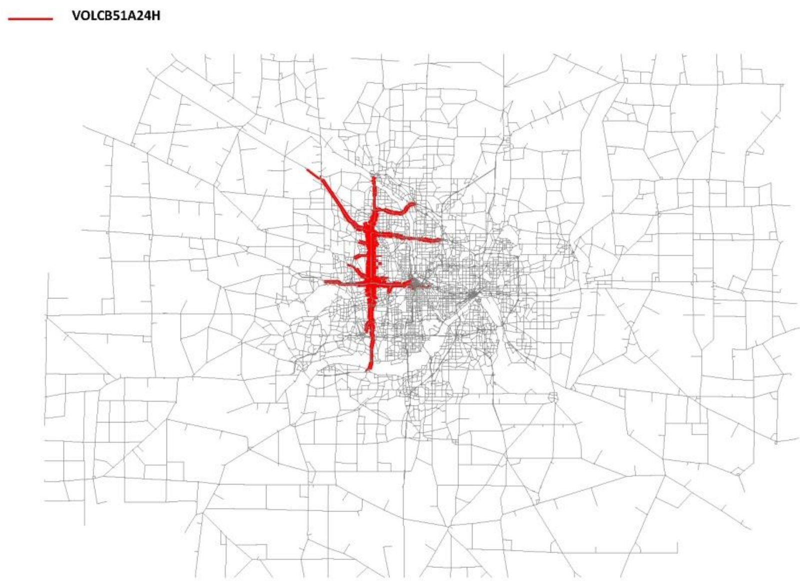
Year 2030 Travel Sheds for Projects Scenario 16: Alt 22B



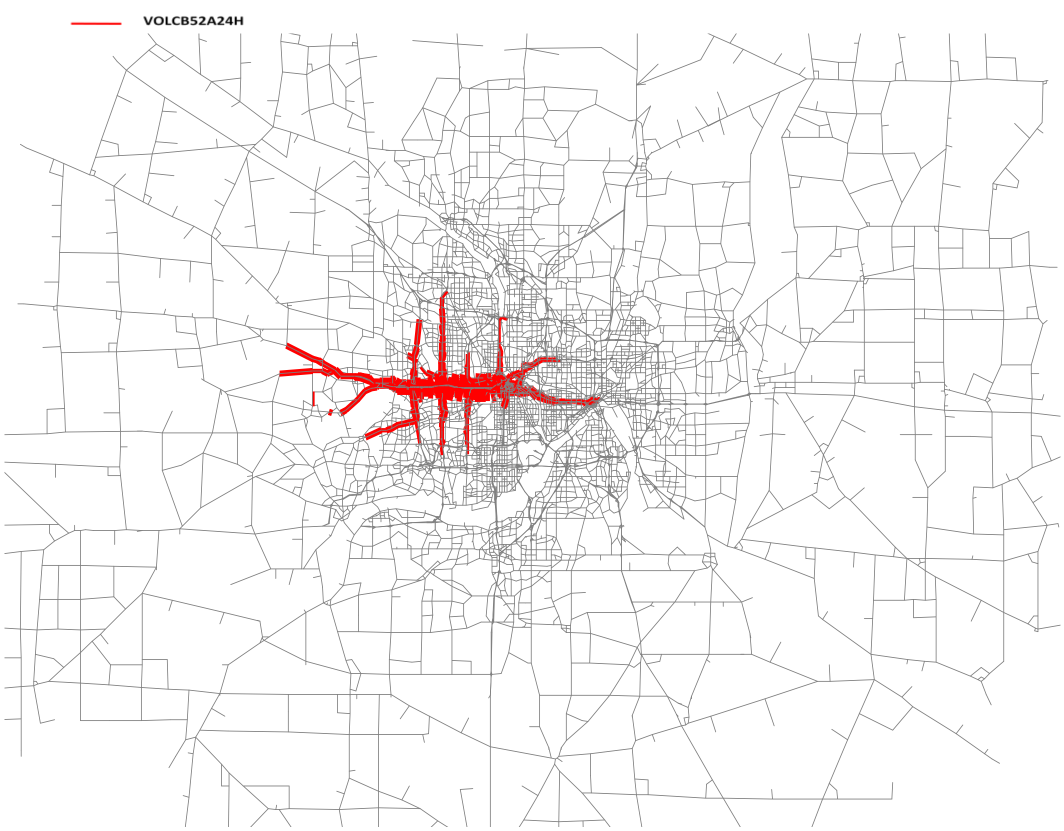
Year 2060 Travel Sheds for Projects Scenario 50: Alt 50A



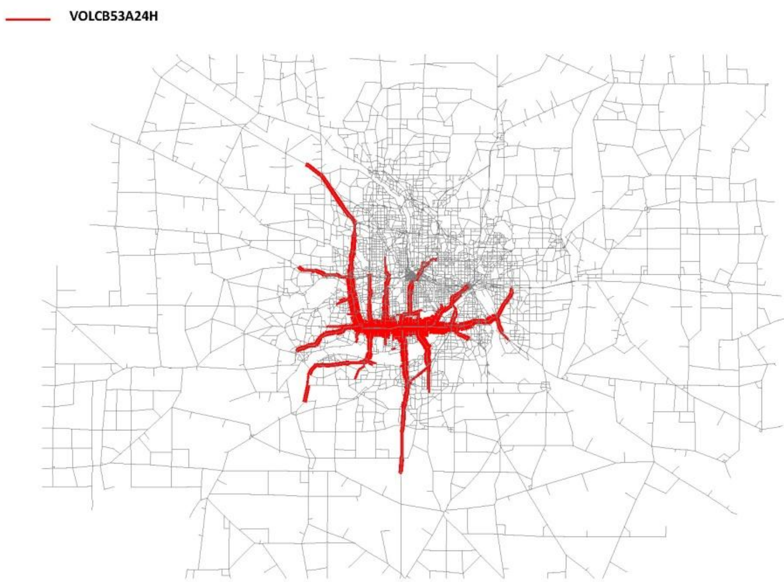
Year 2060 Travel Sheds for Projects Scenario 51: Alt 51A



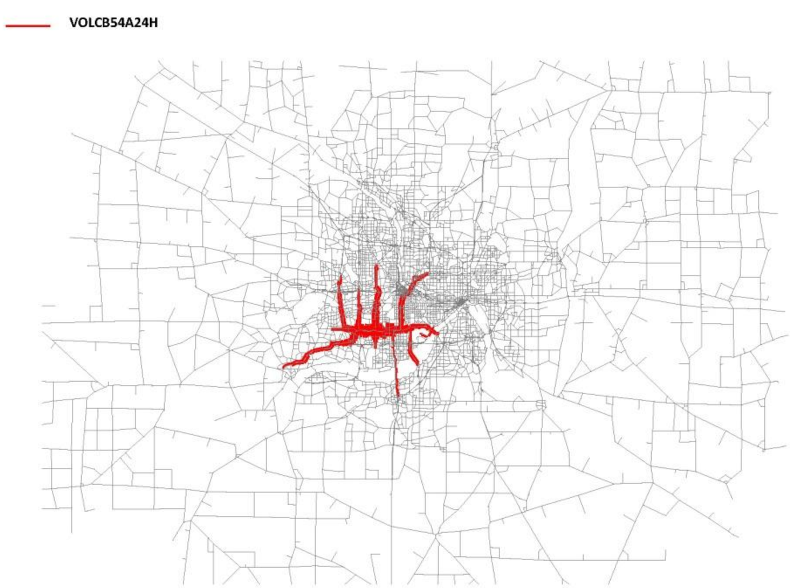
Year 2060 Travel Sheds for Projects Scenario 52: Alt 52A



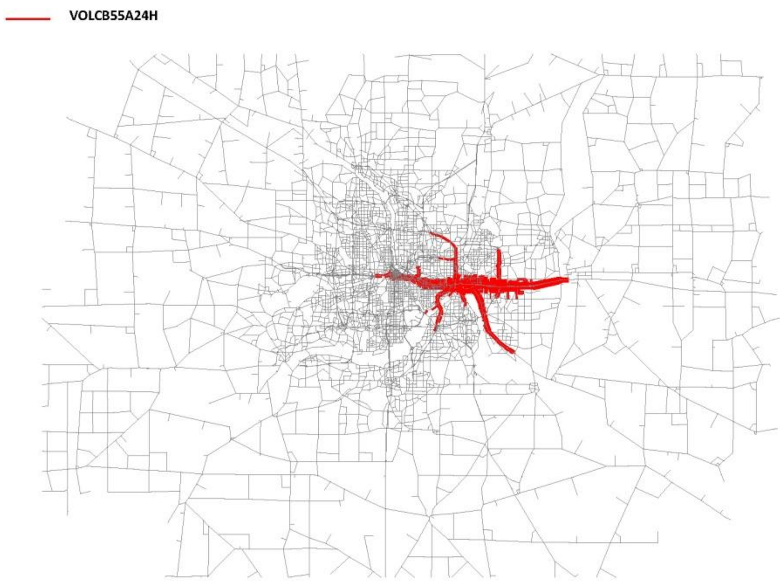
Year 2060 Travel Sheds for Projects Scenario 53: Alt 53A



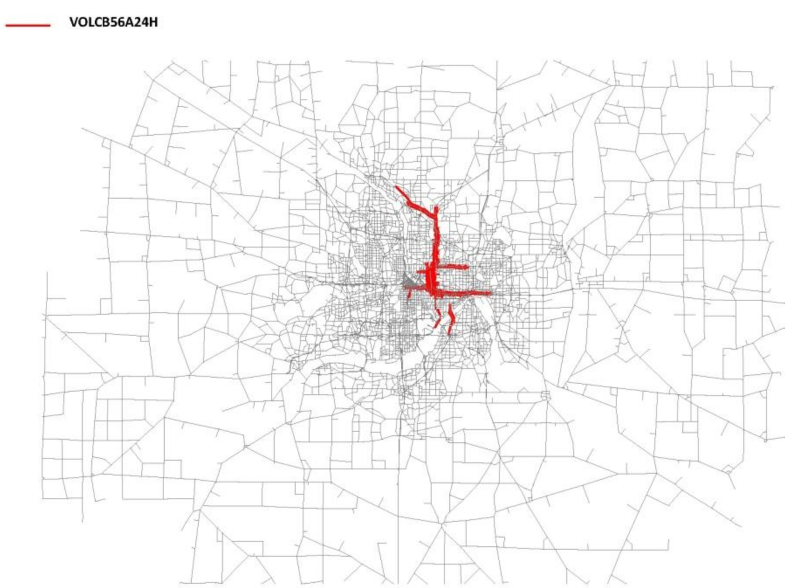
Year 2060 Travel Sheds for Projects Scenario 54: Alt 54A



Year 2060 Travel Sheds for Projects Scenario 55: Alt 55A



Year 2060 Travel Sheds for Projects Scenario 56: Alt 56A



Appendix B:
Selected-Link Regional Assignment Script (example)

```
;Set up 24 time period loop
LOOP HOURLOOP=1,24,1
if (hourloop=1)  ni='op',  tab=1, capfac=2.00, iters=30, hourlycap='offcap', label='12:00am-2:00am'
if (hourloop=2)  ni='op',  tab=2, capfac=1.00, iters=30, hourlycap='offcap', label='2:00am-3:00am'
if (hourloop=3)  ni='op',  tab=3, capfac=1.00, iters=30, hourlycap='offcap', label='3:00am-4:00am'
if (hourloop=4)  ni='op',  tab=4, capfac=1.00, iters=30, hourlycap='offcap', label='4:00am-5:00am'
if (hourloop=5)  ni='op',  tab=5, capfac=1.00, iters=30, hourlycap='offcap', label='5:00am-6:00am'
if (hourloop=6)  ni='am',  tab=6, capfac=0.75, iters=30, hourlycap='amcap',  label='6:00am-6:45am'
if (hourloop=7)  ni='am',  tab=1, capfac=1.00, iters=30, hourlycap='amcap',  label='6:45am-7:45am'
if (hourloop=8)  ni='am',  tab=2, capfac=1.00, iters=30, hourlycap='amcap',  label='7:45am-8:45am'
if (hourloop=9)  ni='am',  tab=3, capfac=1.00, iters=30, hourlycap='amcap',  label='8:45am-9:45am'
if (hourloop=10) ni='op',  tab=4, capfac=1.00, iters=30, hourlycap='offcap', label='9:45am-10:45am'
if (hourloop=11) ni='op',  tab=5, capfac=1.00, iters=30, hourlycap='offcap', label='10:45am-11:45am'
if (hourloop=12) ni='op',  tab=6, capfac=1.00, iters=30, hourlycap='offcap', label='11:45am-12:45pm'
if (hourloop=13) ni='op',  tab=7, capfac=1.00, iters=30, hourlycap='offcap', label='12:45am-1:45pm'
if (hourloop=14) ni='op',  tab=8, capfac=0.75, iters=30, hourlycap='offcap', label='1:45pm-2:30pm'
if (hourloop=15) ni='pm',  tab=1, capfac=1.00, iters=30, hourlycap='pmcap',  label='2:30pm-3:30pm'
if (hourloop=16) ni='pm',  tab=2, capfac=1.00, iters=30, hourlycap='pmcap',  label='3:30pm-4:30pm'
if (hourloop=17) ni='pm',  tab=3, capfac=1.00, iters=30, hourlycap='pmcap',  label='4:30pm-5:30pm'
if (hourloop=18) ni='pm',  tab=4, capfac=0.50, iters=30, hourlycap='pmcap',  label='5:30pm-6:00pm'
if (hourloop=19) ni='op',  tab=1, capfac=1.00, iters=30, hourlycap='offcap', label='6:00pm-7:00pm'
if (hourloop=20) ni='op',  tab=2, capfac=1.00, iters=30, hourlycap='offcap', label='7:00pm-8:00pm'
if (hourloop=21) ni='op',  tab=3, capfac=1.00, iters=30, hourlycap='offcap', label='8:00pm-9:00pm'
if (hourloop=22) ni='op',  tab=4, capfac=1.00, iters=30, hourlycap='offcap', label='9:00pm-10:00pm'
if (hourloop=23) ni='op',  tab=5, capfac=1.00, iters=30, hourlycap='offcap', label='10:00pm-11:00pm'
if (hourloop=24) ni='op',  tab=6, capfac=1.00, iters=30, hourlycap='offcap', label='11:00pm-12:00am'

if (hourloop=1-6)   m1='veh_nt_nhov_eam',m2='veh_nt_hov_eam', m3='eamtrk'
if (hourloop=7-14)   m1='veh_nt_nhov',    m2='veh_nt_hov', m3='trk'
if (hourloop=15-18) m1='veh_nt_nhov_pm', m2='veh_nt_hov_pm', m3='pmtrk'
if (hourloop=19-24) m1='veh_nt_nhov_eve',m2='veh_nt_hov_eve', m3='evetrk'

;Global Parameters
;if (hourloop=1-24)
; year=2030
; iters=30                                 ;Comment out to specify individually
; modelzones=1236                  ;Only Assign Trips in  7-county core
;endif

;distribute intrastep=t

RUN PGM=HWYLOAD
;distributeintrastep processid='nmf', processlist=1-8
    ID TRIP ASSIGNMENT FOR @label@
    FILEI MATI[1] = @m1@.trp        ; Non-HOV trips to be assigned (non-toll)
          MATI[2] = @m2@.trp         ; HOV trips to be assigned (non-toll)
          MATI[3] = @m3@.trp                ; Truck Trips to be assigned (non-toll, non-HOV)
    FILEI NETI= scenario1_attrb.net        ; input network

    FILEO NETO= load2030_scen1_@hourloop@.net       ; output network
          MATO[1]= chktoll_scen1_@hourloop@.mat, MO=1-11, COMBINE=T
          mato[2]= SL_total_scen1_@hourloop@.trp, mo=91-95, dec=5*5, name=30B,35B,36B,39B,44B
          mato[3]= SL_bymode_scen1_@hourloop@.trp, mo=61,71,81,62,72,82,63,73,83,64,74,84,65,75,85, dec=15*5,
             name=30B_SOV,30B_HOV,30B_PAY, 35B_SOV,35B_HOV,35B_PAY, 36B_SOV,36B_HOV,36B_PAY,
                  39B_SOV,39B_HOV,39B_PAY, 44B_SOV,44B_HOV,44B_PAY

    PARAMETERS MAXITERS = @iters@ COMBINE=EQUI    ; maximum number of iterations

    FUNCTION TC[1] = T0 * (2+SQRT(16*(1-(V/C))^2 + 1.361) - 4*(1-(V/C)) - 1.167)
    FUNCTION TC[2] = T0 * (2+SQRT(16*(1-(V/C))^2 + 1.361) - 4*(1-(V/C)) - 1.167)
    FUNCTION TC[3] = T0 * (2+SQRT(16*(1-(V/C))^2 + 1.361) - 4*(1-(V/C)) - 1.167)
    FUNCTION TC[4] = T0 * (2+SQRT(16*(1-(V/C))^2 + 1.361) - 4*(1-(V/C)) - 1.167)
    FUNCTION TC[8] = T0 * (2+SQRT(16*(1-(V/C))^2 + 1.361) - 4*(1-(V/C)) - 1.167)
    FUNCTION TC[10]= T0 * (2+SQRT(16*(1-(V/C))^2 + 1.361) - 4*(1-(V/C)) - 1.167)
    FUNCTION TC[9] = T0
    FUNCTION TC[5] = T0 * (2+SQRT(16*(1-(V/C))^2 + 1.361) - 4*(1-(V/C)) - 1.167)
    FUNCTION TC[6] = T0 * (2+SQRT(25*(1-(V/C))^2 + 1.266) - 5*(1-(V/C)) - 1.125)
    FUNCTION TC[7] = T0 * (2+SQRT(36*(1-(V/C))^2 + 1.210) - 6*(1-(V/C)) - 1.100)
```

```
FUNCTION TC[11] = T0 * (2+SQRT(16*(1-(V/C))^2 + 1.361) - 4*(1-(V/C)) - 1.167)
FUNCTION TC[13] = T0 * (2+SQRT(16*(1-(V/C))^2 + 1.361) - 4*(1-(V/C)) - 1.167)
FUNCTION TC[14] = T0 * (2+SQRT(16*(1-(V/C))^2 + 1.361) - 4*(1-(V/C)) - 1.167)
FUNCTION TC[15] = T0 * (2+SQRT(16*(1-(V/C))^2 + 1.361) - 4*(1-(V/C)) - 1.167)
FUNCTION TC[18] = T0 * (2+SQRT(16*(1-(V/C))^2 + 1.361) - 4*(1-(V/C)) - 1.167)

FUNCTION V=VOL[1] + VOL[2] + VOL[3]

LOOKUP NAME=TOLL,
       LOOKUP[1]=1, RESULT=2,
       INTERPOLATE=Y,
       FAIL=25,800,
       R = '0.00 25',                  ; LOS-Toll table reported by MnDOT
           '0.35 50',
           '0.54 150',
           '0.77 250',
           '0.93 350',
           '1.00 600'

LOOKUP NAME=DIVERT,
       LOOKUP[1]=1, RESULT=2,
       INTERPOLATE=Y,
       FAIL = 5,100,
       R = ' 0.0  5.0',                ; VOT distribution as reported by NuStats
           ' 8.0 50.0',
           '10.0 60.0',
           '16.3 75.0',
           '20.0 81.7',
           '23.7 85.0',
           '31.4 90.5',
           '41.7 95.0',
           '51.8 96.0',
           '58.3 98.0',
           '66.7 98.8'

PHASE=LINKREAD
    IF(LI.ASGNGRP = 0) LINKCLASS = 10
    IF(LI.ASGNGRP > 0) LINKCLASS = LI.ASGNGRP
    T0 = LI.TIME
    LW.HOVFACILITY = LI.HOVFACILITY
    C = LI.@hourlycap@ * @capfac@   ; set capacity equal to a link field ; Note- tolls on in time period 6
    if(LI.asgngrp<>9 & LI.@hourlycap@=0) ADDTOGROUP=3
    IF(LINKCLASS==1-7,9,11,13,14,15) ADDTOGROUP=1
    IF(LW.HOVFACILITY==99) ADDTOGROUP=2      ; I-35W HOV lanes
    IF(LW.HOVFACILITY==1-9) ADDTOGROUP=4      ; I-394 HOT lanes
    IF(LW.HOVFACILITY==5) ADDTOGROUP=5
    IF(LW.HOVFACILITY==6) ADDTOGROUP=6
    if(lw.hovfacility==1,7,9) addtogroup=7
    if(lw.hovfacility==8) addtogroup=8
    if(lw.hovfacility==10) addtogroup=9
    if(lw.hovfacility==11) addtogroup=10
    if(li.I30B==1) addtogroup=11       ; 30B selected link, TH36
    if(li.I35B==1) addtogroup=12       ; 35B selected link, TH65
    if(li.I36B==1) addtogroup=13       ; 36B selected link, TH169/TH10
    if(li.I39B==1) addtogroup=14       ; 39B selected link, TH169
    if(li.I44B==1) addtogroup=15       ; 44B selected link, TH52
    _toll1 = 25
    _toll2 = 25
    _toll3 = 25
    _toll4 = 25
    _toll5 = 25
    _toll6 = 25
ENDPHASE

PHASE=ILOOP                              ; main loop for module
   PATHLOAD PATH=TIME,                   ; build SOV non-pay path based on time
            EXCLUDEGRP=2,3,4,            ; exclude sovs from hov and toll facilities
            MW[1]=PATHCOST

   PATHLOAD PATH=TIME,                   ; build SOV pay path based on time
            EXCLUDEGRP=2,3,              ; exclude sovs from hov facilities
```

```
          MW[2]=PATHCOST,
          MW[3]=_toll1, SELECTGROUP=5,
          MW[4]=_toll2, SELECTGROUP=6,
          mw[13]=_toll3, selectgroup=7,
          mw[14]=_toll4, selectgroup=8,
          mw[15]=_toll5, selectgroup=9,
          mw[16]=_toll6, selectgroup=10

   MW[5] =  MW[3]+MW[4]+mw[13]+mw[14]+mw[15]+mw[16]    ; sum of segment tolls
   MW[6] =  MW[1]-MW[2]                  ; non-pay time minus pay time

   JLOOP
    IF (I==J)
     MW[8] = 0
    ELSE
     IF (MW[6]>0)
      MW[7] = MW[5]/MW[6]                ; toll cost per minute saved
      MW[8] = 100 - DIVERT(1,MW[7])      ; percent willing to pay at this level
      MW[9] = MI.1.@tab@ * MW[8] / 100      ; paying non-hov trips
      MW[10] = MI.1.@tab@ - MW[9]           ; non-paying non-hov trips
      MW[11] = MW[9] * MW[5]            ; revenue for average toll calculations
     ELSE
      MW[7] = -1                        ; flag for 0 min saved
      MW[8] = 0                         ; no-one will pay if there is no savings
      MW[9] = 0                         ; so paying non-hov trips are 0
      MW[10] = MI.1.@tab@                   ; all non-hov trips are non-paying
      MW[11] = 0
     ENDIF
    ENDIF
   ENDJLOOP

   PATHLOAD PATH=TIME,                   ; build non-paying sov path based on time
          EXCLUDEGRP=2,3,4,              ; exclude non-paying sovs from hov/hot facilities
          VOL[1]=MW[10]+MI.3.@tab@,       ; load non-paying sov and input truck trips
          mw[61]=MW[10]+MI.3.@TAB@, selectgroup=11, vol[4]= mw[61],     ; SOV SL:  TH36        30B
          mw[62]=MW[10]+MI.3.@TAB@, selectgroup=12, vol[7]= mw[62],     ; SOV SL:  TH65        35B
          mw[63]=MW[10]+MI.3.@TAB@, selectgroup=13, vol[10]=mw[63],     ; SOV SL:  TH169/TH10  36B
          mw[64]=MW[10]+MI.3.@TAB@, selectgroup=14, vol[13]=mw[64],     ; SOV SL:  TH169       39B
          mw[65]=MW[10]+MI.3.@TAB@, selectgroup=15, vol[16]=mw[65]      ; SOV SL:  TH52        44B

   PATHLOAD PATH=TIME,                   ; build HOV path based on time, no restrictions
          EXCLUDEGRP=3,
          VOL[2]=MI.2.@tab@,             ; load HOV trips from input matrix
          mw[71]=MI.2.@TAB@, selectgroup=11, vol[5]= mw[71],     ; HOV SL:  TH36        30B
          mw[72]=MI.2.@TAB@, selectgroup=12, vol[8]= mw[72],     ; HOV SL:  TH65        35B
          mw[73]=MI.2.@TAB@, selectgroup=13, vol[11]=mw[73],     ; HOV SL:  TH169/TH10  36B
          mw[74]=MI.2.@TAB@, selectgroup=14, vol[14]=mw[74],     ; HOV SL:  TH169       39B
          mw[75]=MI.2.@TAB@, selectgroup=15, vol[17]=mw[75]      ; HOV SL:  TH52        44B

   PATHLOAD PATH=TIME,                   ; build paying sov path based on time
          EXCLUDEGRP=2,3,                ; exclude paying sovs from hov facilities
          VOL[3]=MW[9],                  ; load paying sov trips
          mw[81]=MW[9], selectgroup=11, vol[6]= mw[81],     ; PAY SL:  TH36        30B
          mw[82]=MW[9], selectgroup=12, vol[9]= mw[82],     ; PAY SL:  TH65        35B
          mw[83]=MW[9], selectgroup=13, vol[12]=mw[83],     ; PAY SL:  TH169/TH10  36B
          mw[84]=MW[9], selectgroup=14, vol[15]=mw[84],     ; PAY SL:  TH169       39B
          mw[85]=MW[9], selectgroup=15, vol[18]=mw[85]      ; PAY SL:  TH52        44B

  mw[91] = mw[61] + mw[71] + mw[81]   ; sum selected link for TH36       30B
  mw[92] = mw[62] + mw[72] + mw[82]   ; sum selected link for TH65       35B
  mw[93] = mw[63] + mw[73] + mw[83]   ; sum selected link for TH169/TH10 36B
  mw[94] = mw[64] + mw[74] + mw[84]   ; sum selected link for TH169      39B
  mw[95] = mw[65] + mw[75] + mw[85]   ; sum selected link for TH52       44B
ENDPHASE

PHASE=ADJUST
     IF (LINKNO=1)

      _maxVC1 = 0
      _maxVC2 = 0
      _maxVC3 = 0
```

```
          _maxVC4 = 0
          _maxVC5 = 0
          _maxVC6 = 0
         ENDIF

        IF (LW.HOVFACILITY==5 && c>0)
          IF ((V/C) > _maxVC1) _maxVC1 = (V/C)
         ELSEIF (LW.HOVFACILITY==6 && c>0)
          IF ((V/C) > _maxVC2) _maxVC2 = (V/C)
         ELSEIF (LW.HOVFACILITY==1,7,9 && c>0)
           IF ((V/C) > _maxVC3) _maxVC3 = (V/C)
         ELSEIF (LW.HOVFACILITY==8 && c>0)
           IF ((V/C) > _maxVC4) _maxVC4 = (V/C)
         ELSEIF (LW.HOVFACILITY==10 && c>0)
           IF ((V/C) > _maxVC5) _maxVC5 = (V/C)
         ELSEIF (LW.HOVFACILITY==11 && c>0)
           IF ((V/C) > _maxVC6) _maxVC6 = (V/C)
         ENDIF

        _toll1 = TOLL(1,_maxVC1)
        _toll2 = TOLL(1,_maxVC2)
        _toll3 = toll(1,_maxvc3)
        _toll4 = toll(1,_maxvc4)
        _toll5 = toll(1,_maxvc5)
        _toll6 = toll(1,_maxvc6)
    ENDPHASE
ENDRUN
Endloop
```

Table B-1: Assigned No-Build Network SL Volume Attributes

A1	**30B**	**35B**	**36B**	**39B**	**44B**
Label	TH36	TH65	TH169/TH10	TH169	TH52
SOV	VOL4	VOL7	VOL10	VOL13	VOL16
HOV	VOL5	VOL8	VOL11	VOL14	VOL17
PAY	VOL6	VOL9	VOL12	VOL15	VOL18

A2	**32B**	**43B**	**14A**	**33A**	**1B**
Label	TH55	TH212	I494	TH610	I35E
SOV	VOL4	VOL7	VOL10	VOL13	VOL16
HOV	VOL5	VOL8	VOL11	VOL14	VOL17
PAY	VOL6	VOL9	VOL12	VOL15	VOL18

A3	**6B**	**26B**	**17A**	**19A**	**18A**
Label	I35W	TH252	I494	I694	I494
SOV	VOL4	VOL7	VOL10	VOL13	VOL16
HOV	VOL5	VOL8	VOL11	VOL14	VOL17
PAY	VOL6	VOL9	VOL12	VOL15	VOL18

B1	**20B**	**21B**	**23A**	**3A**	**42B**
Label	I694	I94	I94	I35E	TH169
SOV	VOL4	VOL7	VOL10	VOL13	VOL16
HOV	VOL5	VOL8	VOL11	VOL14	VOL17
PAY	VOL6	VOL9	VOL12	VOL15	VOL18

B2	**4A**	**45A**	**29B**	**41A**	**10A**
Label	I35E	TH77	I35E	TH169	I35W
SOV	VOL4	VOL7	VOL10	VOL13	VOL16
HOV	VOL5	VOL8	VOL11	VOL14	VOL17
PAY	VOL6	VOL9	VOL12	VOL15	VOL18

C1	**7B**	**8B**	**9B**	**11A**	**12A**
Label	I35W	I35W	I35W	I494	I494
SOV	VOL4	VOL7	VOL10	VOL13	VOL16
HOV	VOL5	VOL8	VOL11	VOL14	VOL17
PAY	VOL6	VOL9	VOL12	VOL15	VOL18

C2	**13B**	**27A**	**28B**	**22B**
Label	I494	TH36	TH36	I94
SOV	VOL4	VOL7	VOL10	VOL13
HOV	VOL5	VOL8	VOL11	VOL14
PAY	VOL6	VOL9	VOL12	VOL15

Table B-1: Assigned No-Build Network SL Volume Attributes

D1	**50A**	**51A**	**53A**
Label	I-494	TH 169	I-494
SOV	VOL4	VOL7	VOL10
HOV	VOL5	VOL8	VOL11
PAY	VOL6	VOL9	VOL12

D2	**54A**	**55A**	**56A**
Label	TH 62	I-94	TH 280
SOV	VOL4	VOL7	VOL10
HOV	VOL5	VOL8	VOL11
PAY	VOL6	VOL9	VOL12

Note: for Build scenarios the SOV, HOV and SOV-PAY selected link volume attributes are assigned to VOL4, VOL5, VOL6 in order for the first project listed in Table A-1, VOL7, VOL8, VOL9 in order for the second project listed in Table A-1, and follows this pattern for all corridor projects within a particular build scenario.

Appendix C:
Script to Summarize Build and No-Build Link-Based Performance Statistics, and Output File Contents (example)

```
;;<<Default Template>><<NETWORK>>;;
;Set up 24 time period loop
YEAR='2030'
SCEN='2'

read file=SNNN_AAA_YYYY_delete.dat, 'SNNN' = '@scen@', 'YYYY' = '@YEAR@', 'AAA' = '32B'
read file=SNNN_AAA_YYYY_delete.dat, 'SNNN' = '@scen@', 'YYYY' = '@YEAR@', 'AAA' = '43B'
; read file=SNNN_AAA_YYYY_delete.dat, 'SNNN' = '@scen@', 'YYYY' = '@YEAR@', 'AAA' = '   '
; read file=SNNN_AAA_YYYY_delete.dat, 'SNNN' = '@scen@', 'YYYY' = '@YEAR@', 'AAA' = '   '
; read file=SNNN_AAA_YYYY_delete.dat, 'SNNN' = '@scen@', 'YYYY' = '@YEAR@', 'AAA' = '   '

alt1='32B'
alt2='43B'
alt3='   '
alt4='   '
alt5='   '

LOOP HOURLOOP=1,24,1
; LOOP HOURLOOP=1,2,1

if (hourloop=1)  ni='op',  tab=1, capfac=2.00, iters=30, hourlycap='offcap', label='12:00am-2:00am'
if (hourloop=2)  ni='op',  tab=2, capfac=1.00, iters=30, hourlycap='offcap', label='2:00am-3:00am'
if (hourloop=3)  ni='op',  tab=3, capfac=1.00, iters=30, hourlycap='offcap', label='3:00am-4:00am'
if (hourloop=4)  ni='op',  tab=4, capfac=1.00, iters=30, hourlycap='offcap', label='4:00am-5:00am'
if (hourloop=5)  ni='op',  tab=5, capfac=1.00, iters=30, hourlycap='offcap', label='5:00am-6:00am'
if (hourloop=6)  ni='am',  tab=6, capfac=0.75, iters=30, hourlycap='amcap',  label='6:00am-6:45am'
if (hourloop=7)  ni='am',  tab=1, capfac=1.00, iters=30, hourlycap='amcap',  label='6:45am-7:45am'
if (hourloop=8)  ni='am',  tab=2, capfac=1.00, iters=30, hourlycap='amcap',  label='7:45am-8:45am'
if (hourloop=9)  ni='am',  tab=3, capfac=1.00, iters=30, hourlycap='amcap',  label='8:45am-9:45am'
if (hourloop=10) ni='op',  tab=4, capfac=1.00, iters=30, hourlycap='offcap', label='9:45am-10:45am'
if (hourloop=11) ni='op',  tab=5, capfac=1.00, iters=30, hourlycap='offcap', label='10:45am-11:45am'
if (hourloop=12) ni='op',  tab=6, capfac=1.00, iters=30, hourlycap='offcap', label='11:45am-12:45pm'
if (hourloop=13) ni='op',  tab=7, capfac=1.00, iters=30, hourlycap='offcap', label='12:45am-1:45pm'
if (hourloop=14) ni='op',  tab=8, capfac=0.75, iters=30, hourlycap='offcap', label='1:45pm-2:30pm'
if (hourloop=15) ni='pm',  tab=1, capfac=1.00, iters=30, hourlycap='pmcap',  label='2:30pm-3:30pm'
if (hourloop=16) ni='pm',  tab=2, capfac=1.00, iters=30, hourlycap='pmcap',  label='3:30pm-4:30pm'
if (hourloop=17) ni='pm',  tab=3, capfac=1.00, iters=30, hourlycap='pmcap',  label='4:30pm-5:30pm'
if (hourloop=18) ni='pm',  tab=4, capfac=0.50, iters=30, hourlycap='pmcap',  label='5:30pm-6:00pm'
if (hourloop=19) ni='op',  tab=1, capfac=1.00, iters=30, hourlycap='offcap', label='6:00pm-7:00pm'
if (hourloop=20) ni='op',  tab=2, capfac=1.00, iters=30, hourlycap='offcap', label='7:00pm-8:00pm'
if (hourloop=21) ni='op',  tab=3, capfac=1.00, iters=30, hourlycap='offcap', label='8:00pm-9:00pm'
if (hourloop=22) ni='op',  tab=4, capfac=1.00, iters=30, hourlycap='offcap', label='9:00pm-10:00pm'
if (hourloop=23) ni='op',  tab=5, capfac=1.00, iters=30, hourlycap='offcap', label='10:00pm-11:00pm'
if (hourloop=24) ni='op',  tab=6, capfac=1.00, iters=30, hourlycap='offcap', label='11:00pm-12:00am'


RUN PGM=NETWORK
    ID Performance summary for @hourloop@ @ni@ @label@

FILEI  NETI[1]=..\work\load@YEAR@_NoBuild_A2_@hourloop@.net
       neti[2]=..\..\AllDayTolls\scenario_@SCEN@\Scenario@SCEN@_@YEAR@\load@YEAR@_scen@SCEN@_@hourloop@.net

FILEO  NETO=..\..\AllDayTolls\scenario_@scen@\Scenario@scen@_@YEAR@\load@YEAR@_scen@scen@_pp_@hourloop@.net
fileo printo[1]= ..\..\AllDayTolls\scenario_@scen@\Senario@scen@_@YEAR@\scen@scen@_@alt1@_summaryvht.csv, append=T
fileo printo[2]= ..\..\AllDayTolls\scenario_@scen@\Scenario@scen@_@YEAR@\scen@scen@_@alt1@_summaryvmt.csv, append=T
fileo printo[3]= ..\..\AllDayTolls\scenario_@scen@\Scenario@scen@_@YEAR@\scen@scen@_@alt1@_summaryvcvm.csv, append=T
fileo printo[4]= ..\..\AllDayTolls\scenario_@scen@\Scenario@scen@_@YEAR@\scen@scen@_@alt2@_summaryvht.csv, append=T
fileo printo[5]= ..\..\AllDayTolls\scenario_@scen@\Scenario@scen@_@YEAR@\scen@scen@_@alt2@_summaryvmt.csv, append=T
fileo printo[6]= ..\..\AllDayTolls\scenario_@scen@\Scenario@scen@_@YEAR@\scen@scen@_@alt2@_summaryvcvm.csv, append=T
; fileo printo[7]= ..\..\AllDayTolls\scenario_@scen@\Scenario@scen@_@YEAR@\scen1_@alt3@_summaryvht.csv, append=T
; fileo printo[8]= ..\..\AllDayTolls\scenario_@scen@\Scenario@scen@_@YEAR@\scen1_@alt3@_summaryvmt.csv, append=T
; fileo printo[9]= ..\..\AllDayTolls\scenario_@scen@\Scenario@scen@_@YEAR@\scen1_@alt3@_summaryvcvm.csv, append=T
; fileo printo[10]=..\..\AllDayTolls\scenario_@scen@\Scenario@scen@_@YEAR@\scen1_@alt4@_summaryvht.csv, append=T
; fileo printo[11]=..\..\AllDayTolls\scenario_@scen@\Scenario@scen@_@YEAR@\scen1_@alt4@_summaryvmt.csv, append=T
; fileo printo[12]=..\..\AllDayTolls\scenario_@scen@\Scenario@scen@_@YEAR@\scen1_@alt4@_summaryvcvm.csv, append=T
; fileo printo[13]=..\..\AllDayTolls\scenario_@scen@\Scenario@scen@_@YEAR@\scen1_@alt5@_summaryvht.csv, append=T
; fileo printo[14]=..\..\AllDayTolls\scenario_@scen@\Scenario@scen@_@YEAR@\scen1_@alt5@_summaryvmt.csv, append=T
; fileo printo[15]=..\..\AllDayTolls\scenario_@scen@\Scenario@scen@_@YEAR@\scen1_@alt5@_summaryvcvm.csv, append=T
; fileo printo[16]=..\..\AllDayTolls\scenario_@scen@\Scenario@scen@_@YEAR@\scen1_@alt6@_summaryvht.csv, append=T
; fileo printo[17]=..\..\AllDayTolls\scenario_@scen@\Scenario@scen@_@YEAR@\scen1_@alt6@_summaryvmt.csv, append=T
; fileo printo[18]=..\..\AllDayTolls\scenario_@scen@\Scenario@scen@_@YEAR@\scen1_@alt6@_summaryvcvm.csv, append=T

merge record=true

read file=Array_AAA.dat, 'AAA' = '32b'
read file=Array_AAA.dat, 'AAA' = '43b'
```

```
; read file=Array_AAA.dat, 'AAA' = '36b'
; read file=Array_AAA.dat, 'AAA' = '39b'
; read file=Array_AAA.dat, 'AAA' = '44b'

PROCESS  PHASE=INPUT FILEI=LI.1
read file=max_read_nb.dat, 'AAA' = '33b', 'N1' = '4', 'N2' = '5', 'N3' = '6'
read file=max_read_nb.dat, 'AAA' = '43b', 'N1' = '7', 'N2' = '8', 'N3' = '9'
; read file=max_read_nb.dat, 'AAA' = '36b', 'N1' = '10', 'N2' = '11', 'N3' = '12'
; read file=max_read_nb.dat, 'AAA' = '39b', 'N1' = '13', 'N2' = '14', 'N3' = '15'
; read file=max_read_nb.dat, 'AAA' = '44b', 'N1' = '16', 'N2' = '17', 'N3' = '18'
ENDPROCESS

PHASE=INPUT FILEI=LI.2
read file=max_read_bd.dat, 'AAA' = '32b', 'N1' = '4', 'N2' = '5', 'N3' = '6'
read file=max_read_bd.dat, 'AAA' = '43b', 'N1' = '7', 'N2' = '8', 'N3' = '9'
; read file=max_read_bd.dat, 'AAA' = '36b', 'N1' = '10', 'N2' = '11', 'N3' = '12'
; read file=max_read_bd.dat, 'AAA' = '39b', 'N1' = '13', 'N2' = '14', 'N3' = '15'
; read file=max_read_bd.dat, 'AAA' = '44b', 'N1' = '16', 'N2' = '17', 'N3' = '18'
ENDPROCESS


PROCESS  PHASE=LINKMERGE
;
ntvol = li.1.v_1
btvol = li.2.v_1
read file=max_share.dat, 'AAA' = '32b', 'N1' = '4', 'N2' = '5', 'N3' = '6'
read file=max_share.dat, 'AAA' = '43b', 'N1' = '7', 'N2' = '8', 'N3' = '9'
; read file=max_share.dat, 'AAA' = '36b', 'N1' = '10', 'N2' = '11', 'N3' = '12'
; read file=max_share.dat, 'AAA' = '39b', 'N1' = '13', 'N2' = '14', 'N3' = '15'
; read file=max_share.dat, 'AAA' = '44b', 'N1' = '16', 'N2' = '17', 'N3' = '18'

read file=moes.dat, 'AAA' = '32b'
read file=moes.dat, 'AAA' = '43b'
; read file=moes.dat, 'AAA' = '36b'
; read file=moes.dat, 'AAA' = '39b'
; read file=moes.dat, 'AAA' = '44b'

ENDPROCESS

PROCESS  PHASE=SUMMARY

loop _ag=1,20,1
if(_ag = 1-2,11-12)
  gft='   Freeway'
 elseif (_ag = 3-4,13-14)
  gft='      Ramp'
 elseif (_ag = 15)
  gft='expressway'
 elseif (_ag = 5-6,15-16)
  gft='  Arterial'
 elseif (_ag = 7,17)
  gft=' Collector'
 elseif (_ag = 8,10,18,20)
  gft='Mnged Lane'
 elseif (_ag = 9,19)
  gft='     Local'
endif

if(@hourloop@ = 1-5,10-14,19-24)
  per='OFFPK'
 elseif (@hourloop@ = 6-9)
  per=' AMPK'
 elseif (@hourloop@ = 15-18)
  per=' PMPK'
endif

read file=report.dat, 'AAA' = '32b', 'FILE1' = '1', 'FILE2' = '2', 'FILE3' = '3'
read file=report.dat, 'AAA' = '43b', 'FILE1' = '4', 'FILE2' = '5', 'FILE3' = '6'
; read file=report.dat, 'AAA' = '36b', 'FILE1' = '7', 'FILE2' = '8', 'FILE3' = '9'
; read file=report.dat, 'AAA' = '39b', 'FILE1' = '10', 'FILE2' = '11', 'FILE3' = '12'
; read file=report.dat, 'AAA' = '44b', 'FILE1' = '13', 'FILE2' = '14', 'FILE3' = '15'

endloop
ENDPROCESS
ENDRUN
Endloop
```

SNN_AAA_YYY_delete.dat:

```
*del ..\..\AllDayTolls\scenario_SNNN\ScenarioSNNN_YYYY\scenSNNN_AAA_summaryvht.csv
*del ..\..\AllDayTolls\scenario_SNNN\ScenarioSNNN_YYYY\scenSNNN_AAA_summaryvmt.csv
*del ..\..\AllDayTolls\scenario_SNNN\ScenarioSNNN_YYYY\scenSNNN_AAA_summaryvcvm.csv
```

Array_AAA.dat:

```
Array nbAAAvht=20, bdAAAvht=20, nbAAAvmt=20, bdAAAvmt=20, nbAAAffvht=20, bdAAAffvht=20
Array cnbAAAvht=20, cbdAAAvht=20, cnbAAAvmt=20, cbdAAAvmt=20, cnbAAAffvht=20, cbdAAAffvht=20
Array nbAAAvmvc=20, bdAAAvmvc=20, cnbAAAvmvc=20, cbdAAAvmvc=20
Array nbAAAlm=20, bdAAAlm=20, nbAAAcm=20, bdAAAcm=20
```

Max_read_nb.dat:

```
nb_vAAA = VN1_1 + VN2_1 + VN3_1
_maxsl_nb_AAA = max(_maxsl_nb_AAA,nb_vAAA)
```

Max_read_bd.dat:

```
nb_vAAA = VN1_1 + VN2_1 + VN3_1
_maxsl_nb_AAA = max(_maxsl_nb_AAA,nb_vAAA)
```

Max_share.dat:

```
nb_vAAA = li.1.VNB1_1 + li.1.VNB2_1 + li.1.VNB3_1
bd_vAAA = li.2.VN1_1 + li.2.VN2_1 + li.2.VN3_1
if(_maxsl_nb_AAA > 0.0)
 nbshAAA = nb_vAAA/_maxsl_nb_AAA
else
 nbshAAA = 0.0
endif
if(_maxsl_bd_AAA > 0.0)
 bdshAAA = bd_vAAA/_maxsl_bd_AAA
else
 bdshAAA = 0.0
endif
```

moes.dat:

```
if(nbshAAA >= 0.01 || bdshAAA >= 0.01)
;  congested vht total and for corridor volumes only
 nAAA_vht = li.1.vht_1
 bAAA_vht = li.2.vht_1
 nAAA_vhtc = li.1.time_1 * nb_vAAA / 60
 bAAA_vhtc = li.2.time_1 * bd_vAAA / 60
 if(li.1.hovfacility=1-9)
  cnbAAAvht[8] = cnbAAAvht[8] + nAAA_vhtc
  nbAAAvht[8]  = nbAAAvht[8]  + nAAA_vht
 else
  cnbAAAvht[li.1.asgngrp] = cnbAAAvht[li.1.asgngrp] + nAAA_vhtc
  nbAAAvht[li.1.asgngrp]  = nbAAAvht[li.1.asgngrp]  + nAAA_vht
 endif
 if(li.2.hovfacility=1-9)
  bdAAAvht[8]  = bdAAAvht[8]  + bAAA_vht
  cbdAAAvht[8] = cbdAAAvht[8] + bAAA_vhtc
 else
  bdAAAvht[li.2.asgngrp]  = bdAAAvht[li.2.asgngrp]  + bAAA_vht
  cbdAAAvht[li.2.asgngrp] = cbdAAAvht[li.2.asgngrp] + bAAA_vhtc
 endif

; freeflow vht total and for corridor volumes only
 nAAA_ffvht = li.1.time * li.1.v_1 / 60
 bAAA_ffvht = li.2.time * li.2.v_1 / 60
 nAAA_ffvhtc = li.1.time * nb_vAAA / 60
 bAAA_ffvhtc = li.2.time * bd_vAAA / 60

 if(li.1.hovfacility=1-9)
  cnbAAAffvht[8] = cnbAAAffvht[8] + nAAA_ffvhtc
  nbAAAffvht[8]  = nbAAAffvht[8]  + nAAA_ffvht
 else
  cnbAAAffvht[li.1.asgngrp] = cnbAAAffvht[li.1.asgngrp] + nAAA_ffvhtc
  nbAAAffvht[li.1.asgngrp]  = nbAAAffvht[li.1.asgngrp]  + nAAA_ffvht
 endif
 if(li.2.hovfacility=1-9)
  cbdAAAffvht[8] = cbdAAAffvht[8] + bAAA_ffvhtc
  bdAAAffvht[8]  = bdAAAffvht[8]  + bAAA_ffvht
 else
  cbdAAAffvht[li.2.asgngrp] = cbdAAAffvht[li.2.asgngrp] + bAAA_ffvhtc
  bdAAAffvht[li.2.asgngrp]  = bdAAAffvht[li.2.asgngrp]  + bAAA_ffvht
 endif
; vmt total and for corridor volumes only
 nAAA_vmt = li.1.vdt_1
 bAAA_vmt = li.2.vdt_1
 nAAA_vmtc = li.1.distance * nb_vAAA
 bAAA_vmtc = li.2.distance * bd_vAAA

 if(li.1.hovfacility=1-9)
  cnbAAAvmt[8] = cnbAAAvmt[8] + nAAA_vmtc
  nbAAAvmt[8]  = nbAAAvmt[8]  + nAAA_vmt
 else
  cnbAAAvmt[li.1.asgngrp] = cnbAAAvmt[li.1.asgngrp] + nAAA_vmtc
  nbAAAvmt[li.1.asgngrp]  = nbAAAvmt[li.1.asgngrp]  + nAAA_vmt
 endif

 if(li.2.hovfacility=1-9)
  cbdAAAvmt[8] = cbdAAAvmt[8] + bAAA_vmtc
  bdAAAvmt[8]  = bdAAAvmt[8]  + bAAA_vmt
 else
  cbdAAAvmt[li.2.asgngrp] = cbdAAAvmt[li.2.asgngrp] + bAAA_vmtc
  bdAAAvmt[li.2.asgngrp]  = bdAAAvmt[li.2.asgngrp]  + bAAA_vmt
 endif

; v/c
 nAAA_vc = li.1.vc_1
 bAAA_vc = li.2.vc_1
 nAAA_vci = min(20,int(10*nAAA_vc))
 bAAA_vci = min(20,int(10*bAAA_vc))
```

```
 nbAAAvmvc[nAAA_vci] = nbAAAvmvc[nAAA_vci] + nAAA_vmt
 bdAAAvmvc[bAAA_vci] = bdAAAvmvc[bAAA_vci] + bAAA_vmt
 cnbAAAvmvc[nAAA_vci] = cnbAAAvmvc[nAAA_vci] + nAAA_vmtc
 cbdAAAvmvc[bAAA_vci] = cbdAAAvmvc[bAAA_vci] + bAAA_vmtc

; lane-miles and center-line miles by v/c
nbAAAlm[nAAA_vci] = nbAAAlm[nAAA_vci] + li.1.numlanes*li.1.distance
bdAAAlm[nAAA_vci] = bdAAAlm[nAAA_vci] + li.2.numlanes*li.2.distance

nbAAAcm[nAAA_vci] = nbAAAcm[nAAA_vci] + li.1.distance
bdAAAcm[nAAA_vci] = bdAAAcm[nAAA_vci] + li.2.distance

; volumes, total and for corridor only
 nAAA_vol = li.1.v_1
 bAAA_vol = li.2.v_1
 nAAA_volc = nb_vAAA
 bAAA_volc = bd_vAAA
endif
```

Report.dat:

```
  if(_ag=1 && @hourloop@=1) print csv=T, list=" hour"," length"," period"," ftype","  Genftype","    nbvht",
   "    bdvht","  nbffvht","  bdffvht","   cnbvht","   cbdvht"," cnbffvht"," cbdffvht",
     printo=FILE1
  print csv=T, list = @hourloop@(5), @capfac@(7.2), per(7R), _ag(6), gft(10R),
        nbAAAvht[_ag](12.3),  bdAAAvht[_ag],  nbAAAffvht[_ag],  bdAAAffvht[_ag],
       cnbAAAvht[_ag],       cbdAAAvht[_ag], cnbAAAffvht[_ag], cbdAAAffvht[_ag], printo=FILE1

  if(_ag=1 && @hourloop@=1) print csv=T, list=" hour"," length"," period"," ftype","  Genftype",
     "    nbvmt","    bdvmt","   cnbvmt","   cbdvmt", printo=FILE2
  print csv=T, list = @hourloop@(5), @capfac@(7.2), per(7R), _ag(6), gft(10R),
        nbAAAvmt[_ag](12.3), bdAAAvmt[_ag], cnbAAAvmt[_ag], cbdAAAvmt[_ag], printo=FILE2

  if(_ag=1 && @hourloop@=1) print csv=T, list=" hour"," length"," period","   v/c","    nbvmt","    bdvmt",
     "   cnbvmt","   cbdvmt","   nblnmi","   bdlnmi","   nbclmi","   bdclmi", printo=FILE3
  _vc = _ag/10
  print csv=T, list = @hourloop@(5), @capfac@(7.2), per(7R), _vc(6.2),
        nbAAAvmvc[_ag](12.3), bdAAAvmvc[_ag], cnbAAAvmvc[_ag], cbdAAAvmvc[_ag],
        nbAAAlm[_ag], bdAAAlm[_ag], nbAAAcm[_ag], bdAAAcm[_ag], printo=FILE3
```

VMT link summary output file (scen<<scenario#>>_<<corridor>>_summaryvmt.csv):

Hour	length	period	ftype	Genftype	nbvmt	bdvmt	cnbvmt	cbdvmt
1	2	OFFPK	1	Freeway	18843.44	18838.03	573.19	570.03
1	2	OFFPK	2	Freeway	3895.753	3901.21	1100.74	1110.17
1	2	OFFPK	3	Ramp	120.344	120.37	5.96	5.95

Where:
All totals are based on links in travel shed (selected volume > 1% of max selected link volume)
Nbvmt – No-Build VMT, based on total volumes
Bdvmt – Build VMT, based on total volumes
Cnbvmt – No-Build VMT, based on corridor selected link volumes
Cbdvmt – Build VMT, based on corridor selected link volumes
Hour – assignment period
Length – length of assignment period
Period – description of period type
Ftype – facility/lane type
GenFtype – general facility/lane type
All hour/facility types are listed for a given corridor alternative.

VHT link summary output file (scen<<scenario#>>_<<corridor>>_summaryvht.csv):

hour	length	period	ftype	Genftype	nbvht	bdvht	nbffvht	bdffvht	cnbvht	cbdvht	cnbffvht	cbdffvht
1	2	OFFPK	1	Freeway	296.746	296.65	294.85	294.76	8.77	8.71	8.72	8.66
1	2	OFFPK	2	Freeway	55.018	55.09	54.69	54.76	14.99	15.12	14.91	15.04
1	2	OFFPK	3	Ramp	3.155	3.16	3.11	3.11	0.16	0.15	0.15	0.15
1	2	OFFPK	4	Ramp	12.914	12.9	12.81	12.8	2.69	2.69	2.67	2.66

Where:

All totals are based on links in travel shed (selected volume > 1% of max selected link volume)
Nbvht – No-Build VHT, based on total volumes and congested time
Bdvht – Build VHT, based on total volumes and congested time
Nbffvht – No-Build VHT, based on total volumes and free-flow time
Bdffvht – Build VHT, based on total volumes and free-flow time
Cnbvht – No-Build VHT, based on corridor selected link volumes
Cbdvht – Build VHT, based on corridor selected link volumes
cnNbffvht – No-Build VHT, based on selected link volumes and free-flow time
cbdffvht – Build VHT, based on selected link volumes and free-flow time
Hour – assignment period
Length – length of assignment period
Period – description of period type
Ftype – facility/lane type
GenFtype – general facility/lane type
All hour/facility types are listed for a given corridor alternative.

VHT link summary output file (scen<<scenario#>>_<<corridor>>_summaryvcvm.csv):

hour	length	period	v/c	nbvmt	bdvmt	cnbvmt	cbdvmt	nblnmi	bdlnmi	nbclmi	bdclmi
1	2	OFFPK	0.1	1081.847	717.89	430.28	66.62	6.31	8.34	4.47	4.47
1	2	OFFPK	0.2	150.868	150.85	1.38	1.38	0.78	0.78	0.39	0.39
1	2	OFFPK	0.3	0	0	0	0	0	0	0	0
1	2	OFFPK	0.4	0	0	0	0	0	0	0	0
1	2	OFFPK	0.5	0	0	0	0	0	0	0	0

Where:

All totals are based on links in travel shed (selected volume > 1% of max selected link volume)
Nbvmt – No-Build VMT, based on total volumes
Bdvmt – Build VMT, based on total volumes
Cnbvmt – No-Build VMT, based on corridor selected link volumes
Cbdvmt – Build VMT, based on corridor selected link volumes
Nblnmi – No-Build lane-miles, based on total volumes
Bdlnmi – Build lane-miles, based on total volumes
Nbclnmi – No-Build lane-miles, based on selected link volumes
Bdclnmi – Build lane-miles, based on selected link volumes
Hour – assignment period
Length – length of assignment period
Period – description of period type
v/c – volume to capacity (aggregated by tenths, 0 to 2.0 by 0.1)

All hour/volume to capacity ranges are listed for a given corridor alternative.

Appendix D:
Script to Consolidate and Summarize Matrix-Based Performance Statistics (example)

Person-Trip Consolidation:

```
;Set up 24 time period loop
year='2030'
bdnbd='BD'
scen=4
alt1= '1B'
alt2= '6B'
alt3= '26B'
alt4= '   '
alt5= '   '

cc2=' '
cc3=' '
cc4='; '
cc5='; '

altct=3

LOOP HOURLOOP=1,24,1

if (hourloop=1)  ni='op', per='OP', tab=1, capfac=2.00, iters=30, hourlycap='offcap', label='12:00am-2:00am'
if (hourloop=2)  ni='op', per='OP', tab=2, capfac=1.00, iters=30, hourlycap='offcap', label='2:00am-3:00am'
if (hourloop=3)  ni='op', per='OP', tab=3, capfac=1.00, iters=30, hourlycap='offcap', label='3:00am-4:00am'
if (hourloop=4)  ni='op', per='OP', tab=4, capfac=1.00, iters=30, hourlycap='offcap', label='4:00am-5:00am'
if (hourloop=5)  ni='op', per='OP', tab=5, capfac=1.00, iters=30, hourlycap='offcap', label='5:00am-6:00am'
if (hourloop=6)  ni='am', per='OP', tab=6, capfac=0.75, iters=30, hourlycap='amcap',  label='6:00am-6:45am'
if (hourloop=7)  ni='am', per='PK', tab=1, capfac=1.00, iters=30, hourlycap='amcap',  label='6:45am-7:45am'
if (hourloop=8)  ni='am', per='PK', tab=2, capfac=1.00, iters=30, hourlycap='amcap',  label='7:45am-8:45am'
if (hourloop=9)  ni='am', per='PK', tab=3, capfac=1.00, iters=30, hourlycap='amcap',  label='8:45am-9:45am'
if (hourloop=10) ni='op', per='OP', tab=4, capfac=1.00, iters=30, hourlycap='offcap', label='9:45am-10:45am'
if (hourloop=11) ni='op', per='OP', tab=5, capfac=1.00, iters=30, hourlycap='offcap', label='10:45am-11:45am'
if (hourloop=12) ni='op', per='OP', tab=6, capfac=1.00, iters=30, hourlycap='offcap', label='11:45am-12:45pm'
if (hourloop=13) ni='op', per='OP', tab=7, capfac=1.00, iters=30, hourlycap='offcap', label='12:45am-1:45pm'
if (hourloop=14) ni='op', per='OP', tab=8, capfac=0.75, iters=30, hourlycap='offcap', label='1:45pm-2:30pm'
if (hourloop=15) ni='pm', per='PK', tab=1, capfac=1.00, iters=30, hourlycap='pmcap',  label='2:30pm-3:30pm'
if (hourloop=16) ni='pm', per='PK', tab=2, capfac=1.00, iters=30, hourlycap='pmcap',  label='3:30pm-4:30pm'
if (hourloop=17) ni='pm', per='PK', tab=3, capfac=1.00, iters=30, hourlycap='pmcap',  label='4:30pm-5:30pm'
if (hourloop=18) ni='pm', per='PK', tab=4, capfac=0.50, iters=30, hourlycap='pmcap',  label='5:30pm-6:00pm'
if (hourloop=19) ni='op', per='OP', tab=1, capfac=1.00, iters=30, hourlycap='offcap', label='6:00pm-7:00pm'
if (hourloop=20) ni='op', per='OP', tab=2, capfac=1.00, iters=30, hourlycap='offcap', label='7:00pm-8:00pm'
if (hourloop=21) ni='op', per='OP', tab=3, capfac=1.00, iters=30, hourlycap='offcap', label='8:00pm-9:00pm'
if (hourloop=22) ni='op', per='OP', tab=4, capfac=1.00, iters=30, hourlycap='offcap', label='9:00pm-10:00pm'
if (hourloop=23) ni='op', per='OP', tab=5, capfac=1.00, iters=30, hourlycap='offcap', label='10:00pm-11:00pm'
if (hourloop=24) ni='op', per='OP', tab=6, capfac=1.00, iters=30, hourlycap='offcap', label='11:00pm-12:00am'

RUN PGM=MATRIX

ID Matrix PT Summary for @label@
; The MATRIX module does not have any explicit phases.  The module does run within an implied ILOOP
; where I is the origin zones.  All user statements in the module are processed once for each origin.
; Matrix computation (MW[#]=) are solved for all values of J for each I.  Thus for a given origin zone I
; the values for all destination zones J are automatically computed.  The user can control the computations
; at each J by using a JLOOP.

FILEI  MATI[1]=HBW_@per@_MODE.TRP
       MATI[2]=HBWR_@per@_MODE.TRP
       MATI[3]=HBO_@per@_MODE.TRP
       MATI[4]=HBSCH_@per@_MODE.TRP
       MATI[5]=HBU_@per@_MODE.TRP
       MATI[6]=HBSH_@per@_MODE.TRP
       MATI[7]=NHBW_@per@_MODE.TRP
       MATI[8]=NHBO_@per@_MODE.TRP
       MATI[9]=chktoll_scen@scen@_@hourloop@.mat
       MATI[10]=SL_total_scen@scen@_@hourloop@.trp

FILEO MATO=@bdnbd@_YR@year@_PT_hour_@hourloop@_alt_@alt1@.trp, mo=1-8, name=NM,DA,2P,3P,TRN,SL,SOVTIME,HOVTIME,
dec=8*5
@cc2@ MATO[2]=@bdnbd@_YR@year@_PT_hour_@hourloop@_alt_@alt2@.trp, mo=11-18,
name=NM,DA,2P,3P,TRN,SL,SOVTIME,HOVTIME, dec=8*5
@cc3@ MATO[3]=@bdnbd@_YR@year@_PT_hour_@hourloop@_alt_@alt3@.trp, mo=21-28,
name=NM,DA,2P,3P,TRN,SL,SOVTIME,HOVTIME, dec=8*5
@cc4@ MATO[4]=@bdnbd@_YR@year@_PT_hour_@hourloop@_alt_@alt4@.trp, mo=31-38,
name=NM,DA,2P,3P,TRN,SL,SOVTIME,HOVTIME, dec=8*5
@cc5@ MATO[5]=@bdnbd@_YR@year@_PT_hour_@hourloop@_alt_@alt5@.trp, mo=41-48,
name=NM,DA,2P,3P,TRN,SL,SOVTIME,HOVTIME, dec=8*5

mw[6]=mi.10.@alt1@
@cc2@ mw[16]=mi.10.@alt2@
@cc3@ mw[26]=mi.10.@alt3@
```

```
@cc4@ mw[36]=mi.10.@alt4@
@cc5@ mw[46]=mi.10.@alt5@


jloop

if(mw[6] > 0.0)
; save SOV and HOV times
mw[7]=mi.9.1
mw[8]=mi.9.2
; Non-Motorized, NM, output table 1
 mw[1] = mi.1.1 + mi.1.2 + mi.2.1 + mi.2.2 + mi.3.1 + mi.3.2 + mi.4.1 + mi.4.2 +
         mi.5.1 + mi.5.2 + mi.6.1 + mi.6.2 + mi.7.1 + mi.7.2 + mi.8.1 + mi.8.2
;  Drive-Alone, DA, output table 2
 mw[2] = mi.1.3 + mi.1.4 + mi.2.3 + mi.2.4 + mi.3.3 + mi.3.4 + mi.4.3 + mi.4.4 +
         mi.5.3 + mi.5.4 + mi.6.3 + mi.6.4 + mi.7.3 + mi.7.4 + mi.8.3 + mi.8.4
;  2-Person Auto, 2P, output table 3
 mw[3] = mi.1.5 + mi.1.6 + mi.1.9 + mi.1.10 + mi.2.5 + mi.2.6 + mi.2.9 + mi.2.10 +
         mi.3.5 + mi.3.6 + mi.3.9 + mi.3.10 + mi.4.5 + mi.4.6 + mi.4.9 + mi.4.10 +
         mi.5.5 + mi.5.6 + mi.5.9 + mi.5.10 + mi.6.5 + mi.6.6 + mi.6.9 + mi.6.10 +
         mi.7.5 + mi.7.6 + mi.7.9 + mi.7.10 + mi.8.5 + mi.8.6 + mi.8.9 + mi.8.10
;  3+ Person Auto, 3P, output table 4
 mw[4] = mi.1.7 + mi.1.8 + mi.1.11 + mi.1.12 + mi.2.7 + mi.2.8 + mi.2.11 + mi.2.12 +
         mi.3.7 + mi.3.8 + mi.3.11 + mi.3.12 + mi.4.7 + mi.4.8 + mi.4.11 + mi.4.12 +
         mi.5.7 + mi.5.8 + mi.5.11 + mi.5.12 + mi.6.7 + mi.6.8 + mi.6.11 + mi.6.12 +
         mi.7.7 + mi.7.8 + mi.7.11 + mi.7.12 + mi.8.7 + mi.8.8 + mi.8.11 + mi.8.12
;  Transit, TRN, output table 5
 mw[5] = mi.1.13 + mi.1.14 + mi.1.15 + mi.1.16 + mi.1.17 + mi.1.18 + mi.1.19 + mi.1.20 +
         mi.1.21 + mi.1.22 + mi.1.23 + mi.1.24 + mi.1.25 + mi.1.26 + mi.1.27 + mi.1.28 +
         mi.2.13 + mi.2.14 + mi.2.15 + mi.2.16 + mi.2.17 + mi.2.18 + mi.2.19 + mi.2.20 +
         mi.2.21 + mi.2.22 + mi.2.23 + mi.2.24 + mi.2.25 + mi.2.26 + mi.2.27 + mi.2.28 +
         mi.3.13 + mi.3.14 + mi.3.15 + mi.3.16 + mi.3.17 + mi.3.18 + mi.3.19 + mi.3.20 +
         mi.3.21 + mi.3.22 + mi.3.23 + mi.3.24 + mi.3.25 + mi.3.26 + mi.3.27 + mi.3.28 +
         mi.4.13 + mi.4.14 + mi.4.15 + mi.4.16 + mi.4.17 + mi.4.18 + mi.4.19 + mi.4.20 +
         mi.4.21 + mi.4.22 + mi.4.23 + mi.4.24 + mi.4.25 + mi.4.26 + mi.4.27 + mi.4.28 +
         mi.5.13 + mi.5.14 + mi.5.15 + mi.5.16 + mi.5.17 + mi.5.18 + mi.5.19 + mi.5.20 +
         mi.5.21 + mi.5.22 + mi.5.23 + mi.5.24 + mi.5.25 + mi.5.26 + mi.5.27 + mi.5.28 +
         mi.6.13 + mi.6.14 + mi.6.15 + mi.6.16 + mi.6.17 + mi.6.18 + mi.6.19 + mi.6.20 +
         mi.6.21 + mi.6.22 + mi.6.23 + mi.6.24 + mi.6.25 + mi.6.26 + mi.6.27 + mi.6.28 +
         mi.7.13 + mi.7.14 + mi.7.15 + mi.7.16 + mi.7.17 + mi.7.18 + mi.7.19 + mi.7.20 +
         mi.7.21 + mi.7.22 + mi.7.23 + mi.7.24 + mi.7.25 + mi.7.26 + mi.7.27 + mi.7.28 +
         mi.8.13 + mi.8.14 + mi.8.15 + mi.8.16 + mi.8.17 + mi.8.18 + mi.8.19 + mi.8.20 +
         mi.8.21 + mi.8.22 + mi.8.23 + mi.8.24 + mi.8.25 + mi.8.26 + mi.8.27 + mi.8.28
endif

@cc2@ if(mw[16] > 0.0)
; save SOV and HOV times
@cc2@ mw[17]=mi.9.1
@cc2@ mw[18]=mi.9.2
; Non-Motorized, NM, output table 1
@cc2@  mw[11] = mi.1.1 + mi.1.2 + mi.2.1 + mi.2.2 + mi.3.1 + mi.3.2 + mi.4.1 + mi.4.2 +
@cc2@           mi.5.1 + mi.5.2 + mi.6.1 + mi.6.2 + mi.7.1 + mi.7.2 + mi.8.1 + mi.8.2
;  Drive-Alone, DA, output table 2
@cc2@  mw[12] = mi.1.3 + mi.1.4 + mi.2.3 + mi.2.4 + mi.3.3 + mi.3.4 + mi.4.3 + mi.4.4 +
@cc2@           mi.5.3 + mi.5.4 + mi.6.3 + mi.6.4 + mi.7.3 + mi.7.4 + mi.8.3 + mi.8.4
;  2-Person Auto, 2P, output table 3
@cc2@  mw[13] = mi.1.5 + mi.1.6 + mi.1.9 + mi.1.10 + mi.2.5 + mi.2.6 + mi.2.9 + mi.2.10 +
@cc2@           mi.3.5 + mi.3.6 + mi.3.9 + mi.3.10 + mi.4.5 + mi.4.6 + mi.4.9 + mi.4.10 +
@cc2@           mi.5.5 + mi.5.6 + mi.5.9 + mi.5.10 + mi.6.5 + mi.6.6 + mi.6.9 + mi.6.10 +
@cc2@           mi.7.5 + mi.7.6 + mi.7.9 + mi.7.10 + mi.8.5 + mi.8.6 + mi.8.9 + mi.8.10
;  3+ Person Auto, 3P, output table 4
@cc2@  mw[14] = mi.1.7 + mi.1.8 + mi.1.11 + mi.1.12 + mi.2.7 + mi.2.8 + mi.2.11 + mi.2.12 +
@cc2@           mi.3.7 + mi.3.8 + mi.3.11 + mi.3.12 + mi.4.7 + mi.4.8 + mi.4.11 + mi.4.12 +
@cc2@           mi.5.7 + mi.5.8 + mi.5.11 + mi.5.12 + mi.6.7 + mi.6.8 + mi.6.11 + mi.6.12 +
@cc2@           mi.7.7 + mi.7.8 + mi.7.11 + mi.7.12 + mi.8.7 + mi.8.8 + mi.8.11 + mi.8.12
;  Transit, TRN, output table 5
@cc2@  mw[15] = mi.1.13 + mi.1.14 + mi.1.15 + mi.1.16 + mi.1.17 + mi.1.18 + mi.1.19 + mi.1.20 +
@cc2@           mi.1.21 + mi.1.22 + mi.1.23 + mi.1.24 + mi.1.25 + mi.1.26 + mi.1.27 + mi.1.28 +
@cc2@           mi.2.13 + mi.2.14 + mi.2.15 + mi.2.16 + mi.2.17 + mi.2.18 + mi.2.19 + mi.2.20 +
@cc2@           mi.2.21 + mi.2.22 + mi.2.23 + mi.2.24 + mi.2.25 + mi.2.26 + mi.2.27 + mi.2.28 +
@cc2@           mi.3.13 + mi.3.14 + mi.3.15 + mi.3.16 + mi.3.17 + mi.3.18 + mi.3.19 + mi.3.20 +
@cc2@           mi.3.21 + mi.3.22 + mi.3.23 + mi.3.24 + mi.3.25 + mi.3.26 + mi.3.27 + mi.3.28 +
@cc2@           mi.4.13 + mi.4.14 + mi.4.15 + mi.4.16 + mi.4.17 + mi.4.18 + mi.4.19 + mi.4.20 +
@cc2@           mi.4.21 + mi.4.22 + mi.4.23 + mi.4.24 + mi.4.25 + mi.4.26 + mi.4.27 + mi.4.28 +
@cc2@           mi.5.13 + mi.5.14 + mi.5.15 + mi.5.16 + mi.5.17 + mi.5.18 + mi.5.19 + mi.5.20 +
@cc2@           mi.5.21 + mi.5.22 + mi.5.23 + mi.5.24 + mi.5.25 + mi.5.26 + mi.5.27 + mi.5.28 +
@cc2@           mi.6.13 + mi.6.14 + mi.6.15 + mi.6.16 + mi.6.17 + mi.6.18 + mi.6.19 + mi.6.20 +
@cc2@           mi.6.21 + mi.6.22 + mi.6.23 + mi.6.24 + mi.6.25 + mi.6.26 + mi.6.27 + mi.6.28 +
@cc2@           mi.7.13 + mi.7.14 + mi.7.15 + mi.7.16 + mi.7.17 + mi.7.18 + mi.7.19 + mi.7.20 +
@cc2@           mi.7.21 + mi.7.22 + mi.7.23 + mi.7.24 + mi.7.25 + mi.7.26 + mi.7.27 + mi.7.28 +
@cc2@           mi.8.13 + mi.8.14 + mi.8.15 + mi.8.16 + mi.8.17 + mi.8.18 + mi.8.19 + mi.8.20 +
```

```
@cc2@           mi.8.21 + mi.8.22 + mi.8.23 + mi.8.24 + mi.8.25 + mi.8.26 + mi.8.27 + mi.8.28
@cc2@ endif

@cc3@ if(mw[26] > 0.0)
; save SOV and HOV times
@cc3@ mw[27]=mi.9.1
@cc3@ mw[28]=mi.9.2
; Non-Motorized, NM, output table 1
@cc3@  mw[21] = mi.1.1 + mi.1.2 + mi.2.1 + mi.2.2 + mi.3.1 + mi.3.2 + mi.4.1 + mi.4.2 +
@cc3@           mi.5.1 + mi.5.2 + mi.6.1 + mi.6.2 + mi.7.1 + mi.7.2 + mi.8.1 + mi.8.2
;  Drive-Alone, DA, output table 2
@cc3@  mw[22] = mi.1.3 + mi.1.4 + mi.2.3 + mi.2.4 + mi.3.3 + mi.3.4 + mi.4.3 + mi.4.4 +
@cc3@           mi.5.3 + mi.5.4 + mi.6.3 + mi.6.4 + mi.7.3 + mi.7.4 + mi.8.3 + mi.8.4
;  2-Person Auto, 2P, output table 3
@cc3@  mw[23] = mi.1.5 + mi.1.6 + mi.1.9 + mi.1.10 + mi.2.5 + mi.2.6 + mi.2.9 + mi.2.10 +
@cc3@           mi.3.5 + mi.3.6 + mi.3.9 + mi.3.10 + mi.4.5 + mi.4.6 + mi.4.9 + mi.4.10 +
@cc3@           mi.5.5 + mi.5.6 + mi.5.9 + mi.5.10 + mi.6.5 + mi.6.6 + mi.6.9 + mi.6.10 +
@cc3@           mi.7.5 + mi.7.6 + mi.7.9 + mi.7.10 + mi.8.5 + mi.8.6 + mi.8.9 + mi.8.10
;  3+ Person Auto, 3P, output table 4
@cc3@  mw[24] = mi.1.7 + mi.1.8 + mi.1.11 + mi.1.12 + mi.2.7 + mi.2.8 + mi.2.11 + mi.2.12 +
@cc3@           mi.3.7 + mi.3.8 + mi.3.11 + mi.3.12 + mi.4.7 + mi.4.8 + mi.4.11 + mi.4.12 +
@cc3@           mi.5.7 + mi.5.8 + mi.5.11 + mi.5.12 + mi.6.7 + mi.6.8 + mi.6.11 + mi.6.12 +
@cc3@           mi.7.7 + mi.7.8 + mi.7.11 + mi.7.12 + mi.8.7 + mi.8.8 + mi.8.11 + mi.8.12
;  Transit, TRN, output table 5
@cc3@  mw[25] = mi.1.13 + mi.1.14 + mi.1.15 + mi.1.16 + mi.1.17 + mi.1.18 + mi.1.19 + mi.1.20 +
@cc3@           mi.1.21 + mi.1.22 + mi.1.23 + mi.1.24 + mi.1.25 + mi.1.26 + mi.1.27 + mi.1.28 +
@cc3@           mi.2.13 + mi.2.14 + mi.2.15 + mi.2.16 + mi.2.17 + mi.2.18 + mi.2.19 + mi.2.20 +
@cc3@           mi.2.21 + mi.2.22 + mi.2.23 + mi.2.24 + mi.2.25 + mi.2.26 + mi.2.27 + mi.2.28 +
@cc3@           mi.3.13 + mi.3.14 + mi.3.15 + mi.3.16 + mi.3.17 + mi.3.18 + mi.3.19 + mi.3.20 +
@cc3@           mi.3.21 + mi.3.22 + mi.3.23 + mi.3.24 + mi.3.25 + mi.3.26 + mi.3.27 + mi.3.28 +
@cc3@           mi.4.13 + mi.4.14 + mi.4.15 + mi.4.16 + mi.4.17 + mi.4.18 + mi.4.19 + mi.4.20 +
@cc3@           mi.4.21 + mi.4.22 + mi.4.23 + mi.4.24 + mi.4.25 + mi.4.26 + mi.4.27 + mi.4.28 +
@cc3@           mi.5.13 + mi.5.14 + mi.5.15 + mi.5.16 + mi.5.17 + mi.5.18 + mi.5.19 + mi.5.20 +
@cc3@           mi.5.21 + mi.5.22 + mi.5.23 + mi.5.24 + mi.5.25 + mi.5.26 + mi.5.27 + mi.5.28 +
@cc3@           mi.6.13 + mi.6.14 + mi.6.15 + mi.6.16 + mi.6.17 + mi.6.18 + mi.6.19 + mi.6.20 +
@cc3@           mi.6.21 + mi.6.22 + mi.6.23 + mi.6.24 + mi.6.25 + mi.6.26 + mi.6.27 + mi.6.28 +
@cc3@           mi.7.13 + mi.7.14 + mi.7.15 + mi.7.16 + mi.7.17 + mi.7.18 + mi.7.19 + mi.7.20 +
@cc3@           mi.7.21 + mi.7.22 + mi.7.23 + mi.7.24 + mi.7.25 + mi.7.26 + mi.7.27 + mi.7.28 +
@cc3@           mi.8.13 + mi.8.14 + mi.8.15 + mi.8.16 + mi.8.17 + mi.8.18 + mi.8.19 + mi.8.20 +
@cc3@           mi.8.21 + mi.8.22 + mi.8.23 + mi.8.24 + mi.8.25 + mi.8.26 + mi.8.27 + mi.8.28
@cc3@ endif

@cc4@ if(mw[36] > 0.0)
; save SOV and HOV times
@cc4@ mw[37]=mi.9.1
@cc4@ mw[38]=mi.9.2
; Non-Motorized, NM, output table 1
@cc4@  mw[31] = mi.1.1 + mi.1.2 + mi.2.1 + mi.2.2 + mi.3.1 + mi.3.2 + mi.4.1 + mi.4.2 +
@cc4@           mi.5.1 + mi.5.2 + mi.6.1 + mi.6.2 + mi.7.1 + mi.7.2 + mi.8.1 + mi.8.2
;  Drive-Alone, DA, output table 2
@cc4@  mw[32] = mi.1.3 + mi.1.4 + mi.2.3 + mi.2.4 + mi.3.3 + mi.3.4 + mi.4.3 + mi.4.4 +
@cc4@           mi.5.3 + mi.5.4 + mi.6.3 + mi.6.4 + mi.7.3 + mi.7.4 + mi.8.3 + mi.8.4
;  2-Person Auto, 2P, output table 3
@cc4@  mw[33] = mi.1.5 + mi.1.6 + mi.1.9 + mi.1.10 + mi.2.5 + mi.2.6 + mi.2.9 + mi.2.10 +
@cc4@           mi.3.5 + mi.3.6 + mi.3.9 + mi.3.10 + mi.4.5 + mi.4.6 + mi.4.9 + mi.4.10 +
@cc4@           mi.5.5 + mi.5.6 + mi.5.9 + mi.5.10 + mi.6.5 + mi.6.6 + mi.6.9 + mi.6.10 +
@cc4@           mi.7.5 + mi.7.6 + mi.7.9 + mi.7.10 + mi.8.5 + mi.8.6 + mi.8.9 + mi.8.10
;  3+ Person Auto, 3P, output table 4
@cc4@  mw[34] = mi.1.7 + mi.1.8 + mi.1.11 + mi.1.12 + mi.2.7 + mi.2.8 + mi.2.11 + mi.2.12 +
@cc4@           mi.3.7 + mi.3.8 + mi.3.11 + mi.3.12 + mi.4.7 + mi.4.8 + mi.4.11 + mi.4.12 +
@cc4@           mi.5.7 + mi.5.8 + mi.5.11 + mi.5.12 + mi.6.7 + mi.6.8 + mi.6.11 + mi.6.12 +
@cc4@           mi.7.7 + mi.7.8 + mi.7.11 + mi.7.12 + mi.8.7 + mi.8.8 + mi.8.11 + mi.8.12
;  Transit, TRN, output table 5
@cc4@  mw[35] = mi.1.13 + mi.1.14 + mi.1.15 + mi.1.16 + mi.1.17 + mi.1.18 + mi.1.19 + mi.1.20 +
@cc4@           mi.1.21 + mi.1.22 + mi.1.23 + mi.1.24 + mi.1.25 + mi.1.26 + mi.1.27 + mi.1.28 +
@cc4@           mi.2.13 + mi.2.14 + mi.2.15 + mi.2.16 + mi.2.17 + mi.2.18 + mi.2.19 + mi.2.20 +
@cc4@           mi.2.21 + mi.2.22 + mi.2.23 + mi.2.24 + mi.2.25 + mi.2.26 + mi.2.27 + mi.2.28 +
@cc4@           mi.3.13 + mi.3.14 + mi.3.15 + mi.3.16 + mi.3.17 + mi.3.18 + mi.3.19 + mi.3.20 +
@cc4@           mi.3.21 + mi.3.22 + mi.3.23 + mi.3.24 + mi.3.25 + mi.3.26 + mi.3.27 + mi.3.28 +
@cc4@           mi.4.13 + mi.4.14 + mi.4.15 + mi.4.16 + mi.4.17 + mi.4.18 + mi.4.19 + mi.4.20 +
@cc4@           mi.4.21 + mi.4.22 + mi.4.23 + mi.4.24 + mi.4.25 + mi.4.26 + mi.4.27 + mi.4.28 +
@cc4@           mi.5.13 + mi.5.14 + mi.5.15 + mi.5.16 + mi.5.17 + mi.5.18 + mi.5.19 + mi.5.20 +
@cc4@           mi.5.21 + mi.5.22 + mi.5.23 + mi.5.24 + mi.5.25 + mi.5.26 + mi.5.27 + mi.5.28 +
@cc4@           mi.6.13 + mi.6.14 + mi.6.15 + mi.6.16 + mi.6.17 + mi.6.18 + mi.6.19 + mi.6.20 +
@cc4@           mi.6.21 + mi.6.22 + mi.6.23 + mi.6.24 + mi.6.25 + mi.6.26 + mi.6.27 + mi.6.28 +
@cc4@           mi.7.13 + mi.7.14 + mi.7.15 + mi.7.16 + mi.7.17 + mi.7.18 + mi.7.19 + mi.7.20 +
@cc4@           mi.7.21 + mi.7.22 + mi.7.23 + mi.7.24 + mi.7.25 + mi.7.26 + mi.7.27 + mi.7.28 +
@cc4@           mi.8.13 + mi.8.14 + mi.8.15 + mi.8.16 + mi.8.17 + mi.8.18 + mi.8.19 + mi.8.20 +
@cc4@           mi.8.21 + mi.8.22 + mi.8.23 + mi.8.24 + mi.8.25 + mi.8.26 + mi.8.27 + mi.8.28
@cc4@ endif
```

```
@cc5@ if(mw[46] > 0.0)
; save SOV and HOV times
@cc5@ mw[47]=mi.9.1
@cc5@ mw[48]=mi.9.2
; Non-Motorized, NM, output table 1
@cc5@  mw[41] = mi.1.1 + mi.1.2 + mi.2.1 + mi.2.2 + mi.3.1 + mi.3.2 + mi.4.1 + mi.4.2 +
@cc5@           mi.5.1 + mi.5.2 + mi.6.1 + mi.6.2 + mi.7.1 + mi.7.2 + mi.8.1 + mi.8.2
;  Drive-Alone, DA, output table 2
@cc5@  mw[42] = mi.1.3 + mi.1.4 + mi.2.3 + mi.2.4 + mi.3.3 + mi.3.4 + mi.4.3 + mi.4.4 +
@cc5@           mi.5.3 + mi.5.4 + mi.6.3 + mi.6.4 + mi.7.3 + mi.7.4 + mi.8.3 + mi.8.4
;  2-Person Auto, 2P, output table 3
@cc5@  mw[43] = mi.1.5 + mi.1.6 + mi.1.9 + mi.1.10 + mi.2.5 + mi.2.6 + mi.2.9 + mi.2.10 +
@cc5@           mi.3.5 + mi.3.6 + mi.3.9 + mi.3.10 + mi.4.5 + mi.4.6 + mi.4.9 + mi.4.10 +
@cc5@           mi.5.5 + mi.5.6 + mi.5.9 + mi.5.10 + mi.6.5 + mi.6.6 + mi.6.9 + mi.6.10 +
@cc5@           mi.7.5 + mi.7.6 + mi.7.9 + mi.7.10 + mi.8.5 + mi.8.6 + mi.8.9 + mi.8.10
;  3+ Person Auto, 3P, output table 4
@cc5@  mw[44] = mi.1.7 + mi.1.8 + mi.1.11 + mi.1.12 + mi.2.7 + mi.2.8 + mi.2.11 + mi.2.12 +
@cc5@           mi.3.7 + mi.3.8 + mi.3.11 + mi.3.12 + mi.4.7 + mi.4.8 + mi.4.11 + mi.4.12 +
@cc5@           mi.5.7 + mi.5.8 + mi.5.11 + mi.5.12 + mi.6.7 + mi.6.8 + mi.6.11 + mi.6.12 +
@cc5@           mi.7.7 + mi.7.8 + mi.7.11 + mi.7.12 + mi.8.7 + mi.8.8 + mi.8.11 + mi.8.12
;  Transit, TRN, output table 5
@cc5@  mw[45] = mi.1.13 + mi.1.14 + mi.1.15 + mi.1.16 + mi.1.17 + mi.1.18 + mi.1.19 + mi.1.20 +
@cc5@           mi.1.21 + mi.1.22 + mi.1.23 + mi.1.24 + mi.1.25 + mi.1.26 + mi.1.27 + mi.1.28 +
@cc5@           mi.2.13 + mi.2.14 + mi.2.15 + mi.2.16 + mi.2.17 + mi.2.18 + mi.2.19 + mi.2.20 +
@cc5@           mi.2.21 + mi.2.22 + mi.2.23 + mi.2.24 + mi.2.25 + mi.2.26 + mi.2.27 + mi.2.28 +
@cc5@           mi.3.13 + mi.3.14 + mi.3.15 + mi.3.16 + mi.3.17 + mi.3.18 + mi.3.19 + mi.3.20 +
@cc5@           mi.3.21 + mi.3.22 + mi.3.23 + mi.3.24 + mi.3.25 + mi.3.26 + mi.3.27 + mi.3.28 +
@cc5@           mi.4.13 + mi.4.14 + mi.4.15 + mi.4.16 + mi.4.17 + mi.4.18 + mi.4.19 + mi.4.20 +
@cc5@           mi.4.21 + mi.4.22 + mi.4.23 + mi.4.24 + mi.4.25 + mi.4.26 + mi.4.27 + mi.4.28 +
@cc5@           mi.5.13 + mi.5.14 + mi.5.15 + mi.5.16 + mi.5.17 + mi.5.18 + mi.5.19 + mi.5.20 +
@cc5@           mi.5.21 + mi.5.22 + mi.5.23 + mi.5.24 + mi.5.25 + mi.5.26 + mi.5.27 + mi.5.28 +
@cc5@           mi.6.13 + mi.6.14 + mi.6.15 + mi.6.16 + mi.6.17 + mi.6.18 + mi.6.19 + mi.6.20 +
@cc5@           mi.6.21 + mi.6.22 + mi.6.23 + mi.6.24 + mi.6.25 + mi.6.26 + mi.6.27 + mi.6.28 +
@cc5@           mi.7.13 + mi.7.14 + mi.7.15 + mi.7.16 + mi.7.17 + mi.7.18 + mi.7.19 + mi.7.20 +
@cc5@           mi.7.21 + mi.7.22 + mi.7.23 + mi.7.24 + mi.7.25 + mi.7.26 + mi.7.27 + mi.7.28 +
@cc5@           mi.8.13 + mi.8.14 + mi.8.15 + mi.8.16 + mi.8.17 + mi.8.18 + mi.8.19 + mi.8.20 +
@cc5@           mi.8.21 + mi.8.22 + mi.8.23 + mi.8.24 + mi.8.25 + mi.8.26 + mi.8.27 + mi.8.28
@cc5@ endif

endjloop


ENDRUN

endloop

loop ac=1,3,1
if(ac=1) alt= '1B'
if(ac=2) alt= '6B'
if(ac=3) alt= '26B'
if(ac=4) alt= '   '
if(ac=5) alt= '   '


RUN PGM=MATRIX

ID Matrix PT Summary by Period, Off-Peak, @bdnbd@, @year@, @alt@

FILEI  MATI[1]=@bdnbd@_YR@year@_PT_hour_1_alt_@alt@.trp
       MATI[2]=@bdnbd@_YR@year@_PT_hour_2_alt_@alt@.trp
       MATI[3]=@bdnbd@_YR@year@_PT_hour_3_alt_@alt@.trp
       MATI[4]=@bdnbd@_YR@year@_PT_hour_4_alt_@alt@.trp
       MATI[5]=@bdnbd@_YR@year@_PT_hour_5_alt_@alt@.trp
       MATI[6]=@bdnbd@_YR@year@_PT_hour_6_alt_@alt@.trp
       MATI[7]=@bdnbd@_YR@year@_PT_hour_10_alt_@alt@.trp
       MATI[8]=@bdnbd@_YR@year@_PT_hour_11_alt_@alt@.trp
       MATI[9]=@bdnbd@_YR@year@_PT_hour_12_alt_@alt@.trp
       MATI[10]=@bdnbd@_YR@year@_PT_hour_13_alt_@alt@.trp
       MATI[11]=@bdnbd@_YR@year@_PT_hour_14_alt_@alt@.trp
       MATI[12]=@bdnbd@_YR@year@_PT_hour_19_alt_@alt@.trp
       MATI[13]=@bdnbd@_YR@year@_PT_hour_20_alt_@alt@.trp
       MATI[14]=@bdnbd@_YR@year@_PT_hour_21_alt_@alt@.trp
       MATI[15]=@bdnbd@_YR@year@_PT_hour_22_alt_@alt@.trp
       MATI[16]=@bdnbd@_YR@year@_PT_hour_23_alt_@alt@.trp
       MATI[17]=@bdnbd@_YR@year@_PT_hour_24_alt_@alt@.trp


FILEO MATO=@bdnbd@_YR@year@_PT_OFFPEAK_alt_@alt@.trp, mo=1-8,   name=NM,DA,2P,3P,TRN,SL,SOVTIME,HOVTIME,
dec=8*5
array share=24
```

```
jloop

; off-peak shares
mw[6] = mi.1.6 + mi.2.6 + mi.3.6 + mi.4.6 + mi.5.6 + mi.6.6 +
        mi.7.6 + mi.8.6 + mi.9.6 + mi.10.6 + mi.11.6 +
        mi.12.6 + mi.13.6 + mi.14.6 + mi.15.6 + mi.16.6 + mi.17.6
if(mw[6]>0)
 share[1]=mi.1.6/mw[6]
 share[2]=mi.2.6/mw[6]
 share[3]=mi.3.6/mw[6]
 share[4]=mi.4.6/mw[6]
 share[5]=mi.5.6/mw[6]
 share[6]=mi.6.6/mw[6]
 share[10]=mi.7.6/mw[6]
 share[11]=mi.8.6/mw[6]
 share[12]=mi.9.6/mw[6]
 share[13]=mi.10.6/mw[6]
 share[14]=mi.11.6/mw[6]
 share[19]=mi.12.6/mw[6]
 share[20]=mi.13.6/mw[6]
 share[21]=mi.14.6/mw[6]
 share[22]=mi.15.6/mw[6]
 share[23]=mi.16.6/mw[6]
 share[24]=mi.17.6/mw[6]
else
 share[1]=0.0
 share[2]=0.0
 share[3]=0.0
 share[4]=0.0
 share[5]=0.0
 share[6]=0.0
 share[10]=0.0
 share[11]=0.0
 share[12]=0.0
 share[13]=0.0
 share[14]=0.0
 share[19]=0.0
 share[20]=0.0
 share[21]=0.0
 share[22]=0.0
 share[23]=0.0
 share[24]=0.0
endif

mw[1] = mi.1.1*share[1] + mi.2.1*share[2] + mi.3.1*share[3] + mi.4.1*share[4] + mi.5.1*share[5] +
mi.6.1*share[6] +
        mi.7.1*share[10] + mi.8.1*share[11] + mi.9.1*share[12] + mi.10.1*share[13] + mi.11.1*share[14] +
        mi.12.1*share[19] + mi.13.1*share[20] + mi.14.1*share[21] + mi.15.1*share[22] + mi.16.1*share[23] +
mi.17.1*share[24]

mw[2] = mi.1.2*share[1] + mi.2.2*share[2] + mi.3.2*share[3] + mi.4.2*share[4] + mi.5.2*share[5] +
mi.6.2*share[6] +
        mi.7.2*share[10] + mi.8.2*share[11] + mi.9.2*share[12] + mi.10.2*share[13] + mi.11.2*share[14] +
        mi.12.2*share[19] + mi.13.2*share[20] + mi.14.2*share[21] + mi.15.2*share[22] + mi.16.2*share[23] +
mi.17.2*share[24]

mw[3] = mi.1.3*share[1] + mi.2.3*share[2] + mi.3.3*share[3] + mi.4.3*share[4] + mi.5.3*share[5] +
mi.6.3*share[6] +
        mi.7.3*share[10] + mi.8.3*share[11] + mi.9.3*share[12] + mi.10.3*share[13] + mi.11.3*share[14] +
        mi.12.3*share[19] + mi.13.3*share[20] + mi.14.3*share[21] + mi.15.3*share[22] + mi.16.3*share[23] +
mi.17.3*share[24]

mw[4] = mi.1.4*share[1] + mi.2.4*share[2] + mi.3.4*share[3] + mi.4.4*share[4] + mi.5.4*share[5] +
mi.6.4*share[6] +
        mi.7.4*share[10] + mi.8.4*share[11] + mi.9.4*share[12] + mi.10.4*share[13] + mi.11.4*share[14] +
        mi.12.4*share[19] + mi.13.4*share[20] + mi.14.4*share[21] + mi.15.4*share[22] + mi.16.4*share[23] +
mi.17.4*share[24]

mw[5] = mi.1.5*share[1] + mi.2.5*share[2] + mi.3.5*share[3] + mi.4.5*share[4] + mi.5.5*share[5] +
mi.6.5*share[6] +
        mi.7.5*share[10] + mi.8.5*share[11] + mi.9.5*share[12] + mi.10.5*share[13] + mi.11.5*share[14] +
        mi.12.5*share[19] + mi.13.5*share[20] + mi.14.5*share[21] + mi.15.5*share[22] + mi.16.5*share[23] +
mi.17.5*share[24]

mw[7] = mi.1.7*share[1] + mi.2.7*share[2] + mi.3.7*share[3] + mi.4.7*share[4] + mi.5.7*share[5] +
mi.6.7*share[6] +
        mi.7.7*share[10] + mi.8.7*share[11] + mi.9.7*share[12] + mi.10.7*share[13] + mi.11.7*share[14] +
        mi.12.7*share[19] + mi.13.7*share[20] + mi.14.7*share[21] + mi.15.7*share[22] + mi.16.7*share[23] +
mi.17.7*share[24]
```

```
mw[8] = mi.1.8*share[1] + mi.2.8*share[2] + mi.3.8*share[3] + mi.4.8*share[4] + mi.5.8*share[5] +
mi.6.8*share[6] +
        mi.7.8*share[10] + mi.8.8*share[11] + mi.9.8*share[12] + mi.10.8*share[13] + mi.11.8*share[14] +
        mi.12.8*share[19] + mi.13.8*share[20] + mi.14.8*share[21] + mi.15.8*share[22] + mi.16.8*share[23] +
mi.17.8*share[24]

endjloop

ENDRUN

RUN PGM=MATRIX

ID Matrix PT Summary by Period, Off-Peak, @bdnbd@, @year@, @alt@

FILEI  MATI[1]=@bdnbd@_YR@year@_PT_OFFPEAK_alt_@alt@.trp
       MATI[2]=@bdnbd@_YR@year@_PT_hour_7_alt_@alt@.trp
       MATI[3]=@bdnbd@_YR@year@_PT_hour_8_alt_@alt@.trp
       MATI[4]=@bdnbd@_YR@year@_PT_hour_9_alt_@alt@.trp
       MATI[5]=@bdnbd@_YR@year@_PT_hour_15_alt_@alt@.trp
       MATI[6]=@bdnbd@_YR@year@_PT_hour_16_alt_@alt@.trp
       MATI[7]=@bdnbd@_YR@year@_PT_hour_17_alt_@alt@.trp
       MATI[8]=@bdnbd@_YR@year@_PT_hour_18_alt_@alt@.trp

FILEO MATO[1]=@bdnbd@_YR@year@_PT_AMPEAK_alt_@alt@.trp, mo=11-18, name=NM,DA,2P,3P,TRN,SL,SOVTIME,HOVTIME,
dec=8*5
FILEO MATO[2]=@bdnbd@_YR@year@_PT_PMPEAK_alt_@alt@.trp, mo=21-28, name=NM,DA,2P,3P,TRN,SL,SOVTIME,HOVTIME,
dec=8*5
FILEO MATO[3]=@bdnbd@_YR@year@_PT_DAILY_alt_@alt@.trp,  mo=31-38, name=NM,DA,2P,3P,TRN,SL,SOVTIME,HOVTIME,
dec=8*5

array share=24, sharepk=24

jloop

; am-peak shares
mw[16] = mi.2.6 + mi.3.6 + mi.4.6
if(mw[16]>0)
 share[2]=mi.2.6/mw[16]
 share[3]=mi.3.6/mw[16]
 share[4]=mi.4.6/mw[16]
else
 share[2]=0.0
 share[3]=0.0
 share[4]=0.0
endif
mw[46] = mi.2.6 + mi.3.6 + mi.4.6 + mi.5.6 + mi.6.6 + mi.7.6 + mi.8.6
if(mw[46]>0)
 sharepk[7]=mi.2.6/mw[46]
 sharepk[8]=mi.3.6/mw[46]
 sharepk[9]=mi.4.6/mw[46]
 sharepk[15]=mi.5.6/mw[46]
 sharepk[16]=mi.6.6/mw[46]
 sharepk[17]=mi.7.6/mw[46]
 sharepk[18]=mi.8.6/mw[46]
else
 sharepk[7]=0.0
 sharepk[8]=0.0
 sharepk[9]=0.0
 sharepk[15]=0.0
 sharepk[16]=0.0
 sharepk[17]=0.0
 sharepk[18]=0.0
endif

mw[11] = mi.2.1*sharepk[7] + mi.3.1*sharepk[8] + mi.4.1*sharepk[9]
mw[12] = mi.2.2*sharepk[7] + mi.3.2*sharepk[8] + mi.4.2*sharepk[9]
mw[13] = mi.2.3*sharepk[7] + mi.3.3*sharepk[8] + mi.4.3*sharepk[9]
mw[14] = mi.2.4*sharepk[7] + mi.3.4*sharepk[8] + mi.4.4*sharepk[9]
mw[15] = mi.2.5*sharepk[7] + mi.3.5*sharepk[8] + mi.4.5*sharepk[9]
mw[17] = mi.2.7*share[7] + mi.3.7*share[8] + mi.4.7*share[9]
mw[18] = mi.2.8*share[7] + mi.3.8*share[8] + mi.4.8*share[9]

; pm-peak shares
mw[26] = mi.5.6 + mi.6.6 + mi.7.6 + mi.8.6
if(mw[26]>0)
 share[15]=mi.5.6/mw[26]
 share[16]=mi.6.6/mw[26]
 share[17]=mi.7.6/mw[26]
 share[18]=mi.8.6/mw[26]
else
 share[15]=0.0
```

```
 share[16]=0.0
 share[17]=0.0
 share[18]=0.0
endif

mw[21] = mi.5.1*sharepk[15] + mi.6.1*sharepk[16] + mi.7.1*sharepk[17] + mi.8.1*sharepk[18]
mw[22] = mi.5.2*sharepk[15] + mi.6.2*sharepk[16] + mi.7.2*sharepk[17] + mi.8.2*sharepk[18]
mw[23] = mi.5.3*sharepk[15] + mi.6.3*sharepk[16] + mi.7.3*sharepk[17] + mi.8.3*sharepk[18]
mw[24] = mi.5.4*sharepk[15] + mi.6.4*sharepk[16] + mi.7.4*sharepk[17] + mi.8.4*sharepk[18]
mw[25] = mi.5.5*sharepk[15] + mi.6.5*sharepk[16] + mi.7.5*sharepk[17] + mi.8.5*sharepk[18]
mw[27] = mi.5.7*share[15] + mi.6.7*share[16] + mi.7.7*share[17] + mi.8.7*share[18]
mw[28] = mi.5.8*share[15] + mi.6.8*share[16] + mi.7.8*share[17] + mi.8.8*share[18]

; daily totals
mw[31] = mi.1.1 + mw[11] + mw[21]
mw[32] = mi.1.2 + mw[12] + mw[22]
mw[33] = mi.1.3 + mw[13] + mw[23]
mw[34] = mi.1.4 + mw[14] + mw[24]
mw[35] = mi.1.5 + mw[15] + mw[25]

mw[36] = mi.1.6 + mw[16] + mw[26]
if(mw[36]>0)
 opksh=mi.1.6/mw[36]
 ampksh=mw[16]/mw[36]
 pmpksh=mw[26]/mw[36]
else
 opksh=0.0
 ampksh=0.0
 pmpksh=0.0
endif
mw[37] = opksh*mi.1.7 + ampksh*mw[17] + pmpksh*mw[27]
mw[38] = opksh*mi.1.8 + ampksh*mw[18] + pmpksh*mw[28]

endjloop

ENDRUN

endloop
```

Trip Length Frequency Distribution:

```
;;<<Default Template>><<MATRIX>>;;
year='2030'
bdnbd='BD'
alt= '26B'
scen=4

RUN PGM=MATRIX
ID TLFD,  YR@year@, @bdnbd@, alt=@alt@
FILEI MATI[1]=@bdnbd@_YR@year@_PT_DAILY_alt_@alt@.trp
zones=1632
mw[1]=mi.1.1 ; non-motorized
mw[2]=mi.1.2 ; drive-alone
mw[3]=mi.1.3 ; 2-person auto
mw[4]=mi.1.4 ; 3+ person auto
mw[5]=mi.1.5 ; transit
mw[6]=mi.1.6 ; selected link autos
mw[7]=mi.1.7 ; sov time
mw[8]=mi.1.8 ; hov time

mw[10] = mw[3] + mw[4]                            ; share-ride
mw[20] = mw[1] + mw[2] + mw[3] + mw[4] + mw[5]    ; total person-trips

FREQUENCY BASEMW=8,VALUEMW=6,RANGE=0-220-2.5,TITLE='Selected link TLFD'
FREQUENCY BASEMW=7,VALUEMW=2,RANGE=0-220-2.5,TITLE='DA PT TLFD'
FREQUENCY BASEMW=8,VALUEMW=10,RANGE=0-220-2.5,TITLE='SR PT TLFD'


ENDRUN
```

APPENDIX E: ATM MODEL TECH MEMORANDUM

Metropolitan Highway System Investment Study

Evaluation of Active Traffic Management Strategies

Prepared by:
Parsons Brinckerhoff
Telvent Farradyne

April 2010

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1. Introduction

Active Traffic Management (ATM) consists of a suite of technologies which improve the operational efficiency of highway systems by dynamically managing traffic flow and dissemination of information to the users of the system. It has also been seen that ATM helps in reducing the likelihood of accidents related to speed differentials. A brief description for some of these ATM techniques is given below:

1. **Speed Harmonization/Lane Control:** This consists of dynamically adjusting speed limits on a freeway corridor based on the level of congestion. This reduces the risk of accidents and optimizes the flow of vehicles through the corridor.
2. **Queue Warning:** This consists of displaying information about downstream traffic backups to the motorists using Variable Message Signs (VMS). This informs motorists of downstream queuing and lane closures, allowing motorists to select alternate routes or lanes and reduce queue buildup.
3. **Dynamic Re-routing:** This consists of providing information to the motorists regarding alternate routes when there is downstream congestion. Guidance is provided to the motorists to move to alternate routes.
4. **Hard Shoulder Running:** This allows for allowing motorists to use the freeway shoulder during congested periods. It helps in reducing congestion during peak periods. For implementing this strategy the shoulders should be upgraded to full depth pavements and monitored vehicle refuge areas should be constructed for disabled or stopped vehicles.

An evaluation of the various ATM techniques was to choose a technology that would best serve the needs of the Minneapolis-St. Paul region. After considering a dynamic re-routing system and a speed harmonization/ lane control system it was decided that the latter alternative would be the preferred ATM strategy for the region. Six corridors were selected for studying the deployment of the speed harmonization /lane control system. The selection of the corridors was based on the 2005-2007 freeways and major expressway crash map and the 2008 metro freeway congestion maps for the morning and evening peak periods. The corridors selected were:

- I-35 W (SB only)
- I-35 E AND I-694
- TH-36
- I-94 AND I-394
- TH-62
- I-494

This report describes the methodology used for analyzing the implementation of speed harmonization/ lane control on these corridors, the results of the analysis and some key takeaways. A comparative cost-benefit analysis approach was used to analyze the different alternatives. The analysis enabled the development of an ATM deployment strategy and helped integrate it into the long term vision for the region.

2. Methodology

In this study the different alternatives were modeled using the software tool ITS Deployment Analysis System (IDAS). IDAS is a systematic analysis tool for evaluation of the benefits and costs of Intelligent Transportation System (ITS) deployments. The modeling and analysis process involved three major tasks:

1. Modification of the IDAS software to add ATM as an ITS element under Freeway Management Systems
2. Developing the Minneapolis-St. Paul transportation network in IDAS using data from the regional travel demand model.
3. Development of various deployment alternatives and performing cost-benefit analysis.

2.1. IDAS Modification to add ATM

Off the shelf IDAS software does not have a module for ATM deployments. For the purpose of this analysis the IDAS software was modified to add two ATM components. These additions were made under the "Freeway Management System" element available in IDAS. The two ATM elements added to the software were:

1. ATM 3-Lane: This consisted of the gantry and all associated ITS equipment required for ATM implementation on a 3 lane one way freeway. The gantry is assumed to be deployed every half mile and the cost is $300K. The O&M costs are assumed to be 7.5% of capital costs annually and the life of the equipment is assumed to be 100 years. The variation in the cost is assumed to be 10%

2. ATM 4-Lane: This consisted of the gantry and all associated ITS equipment required for ATM implementation on a 4 lane one way freeway. The gantry is assumed to be deployed every half mile and the cost is $300K. The O&M costs are assumed to be 7.5% of capital costs annually and the life of the equipment is assumed to be 100 years. The variation in the cost is assumed to be 10%

Default data for the IDAS software are stored in several spreadsheets. The addition of the ATM deployments to the IDAS software required the revision of the following base spreadsheets.

1. DirectBenefits2_3.xls: This spreadsheet contains the data for the "ITS Library" in IDAS. It provides field notes for observed improvements for each of the different ITS components
2. ITSEntryDefaults2_3.xls: This spreadsheet contains the data for the impact fields; default values and drop down menus displayed when the Edit Impacts button is clicked after ITS deployments are made in IDAS.
3. Equip2_3.xls: This spreadsheet provides the description, specification and prerequisites for each ITS component. It also describes the elements used for each component, their cost values and useful life.
4. Curves2_3.xls: This spreadsheet has the default values for the Volume-delay curves. It defines the speed factor values for varying volume to capacity ratios. The data is defined for urban and suburban/rural freeways, arterials and ramps.

Each of the first three spreadsheets were updated to incorporate ATM 3-Lane and ATM 4-Lane components to the model. The "ITS Library" was updated to reflect the benefits assumed for these deployments (based on European experience). The "ITS EntryDefaults" spreadsheet was updated to add the impact values for the proposed ATM deployment. The "Equipment" spreadsheet was updated to define the components and costs of these two new ATM elements.
The default values in the "Curves" spreadsheet are based on the Bureau of Public records formula for computing speed factor. However the Minneapolis-St.Paul regional travel demand model uses conical delay functions for computing speed factors. The spreadsheet was updated to reflect the values using the conical delay functions.

The modified spreadsheets were renamed as:

1. DirectBenefits2_5.xls
2. ITSEntryDefaults2_5.xls
3. Equip2_5.xls
4. Curves2_5.xls

The modified spreadsheets were imported into the IDAS software for the ATM elements be available in the "ITS Elements" workspace.

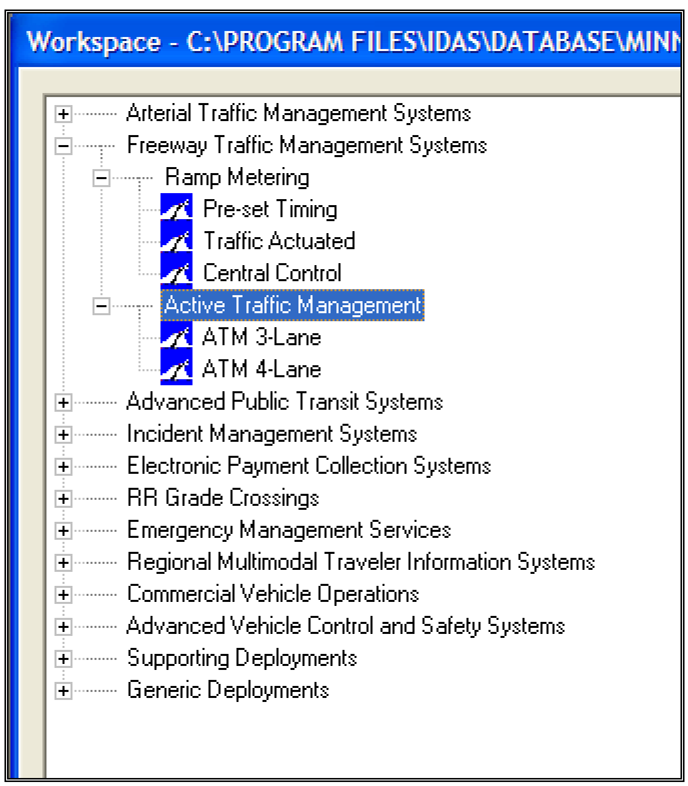


Fig 1: IDAS workspace with ATM elements.

2.2. IDAS Model

The Minneapolis-St.Paul transportation network was developed in IDAS using the data from the CUBE travel demand model (TDM) used by the Metropolitan Council. The data used for building the network included the node coordinate file, the links data file and the origin-destination matrices for each time period and market sector. Three market sectors used in the analysis are:

1. Single Occupancy Vehicles (Avg. Vehicle occupancy = 1.42)
2. High Occupancy Vehicles (Avg. Vehicle occupancy = 2.74)
3. Trucks (Avg. Vehicle occupancy = 1.58)

The alternatives were developed for two time periods using the 2030 TDM data. The periods are:

1. AM Peak Period: 6:00 a.m. – 9:00 a.m.
2. PM Peak Period: 2:30 p.m. – 5:30 p.m.

Seven alternatives were developed and evaluated for each of the two periods. Six alternatives involved deployment of ATM on the six corridors identified earlier and the seventh alternative involved deployment of ATM on all corridors.

The model assumes that ATM deployment (Speed Harmonization/Lane Control) results in reduced accident rate. These result in increased throughput for the corridor. Dynamic message signs which are part of an ATM system help in dissemination of important travel related information to the motorists. This results in improved operational efficiency for the corridor. The primary benefits value assumptions made in the model regarding the impact of deployment of a speed harmonization/lane control system are provided below:

I. Dynamic Message Sign
   - Percent Vehicles passing sign that save time = 28%
   - Percent time the sign is turned on and disseminating information=10%
   - Average amount of time savings (min.) = 11

II. Speed Harmonization/Lane Control
   1. Capacity Change: 5%
   2. Accident Rate Reductions:
      - Fatality =30%
      - Injury = 30%
      - Property Damage = 16%

A discount rate of 5% was assumed in the Costs Module.. An inflation rate of 5% was assumed in the Alternatives Comparison Module. The variation in the cost values was assumed to be +/- 10%. The annual operations and maintenance costs for the speed harmonization/ lane control system was assumed to be 7.5% of the capital costs. All results for this analysis are reported in 2010 dollars.

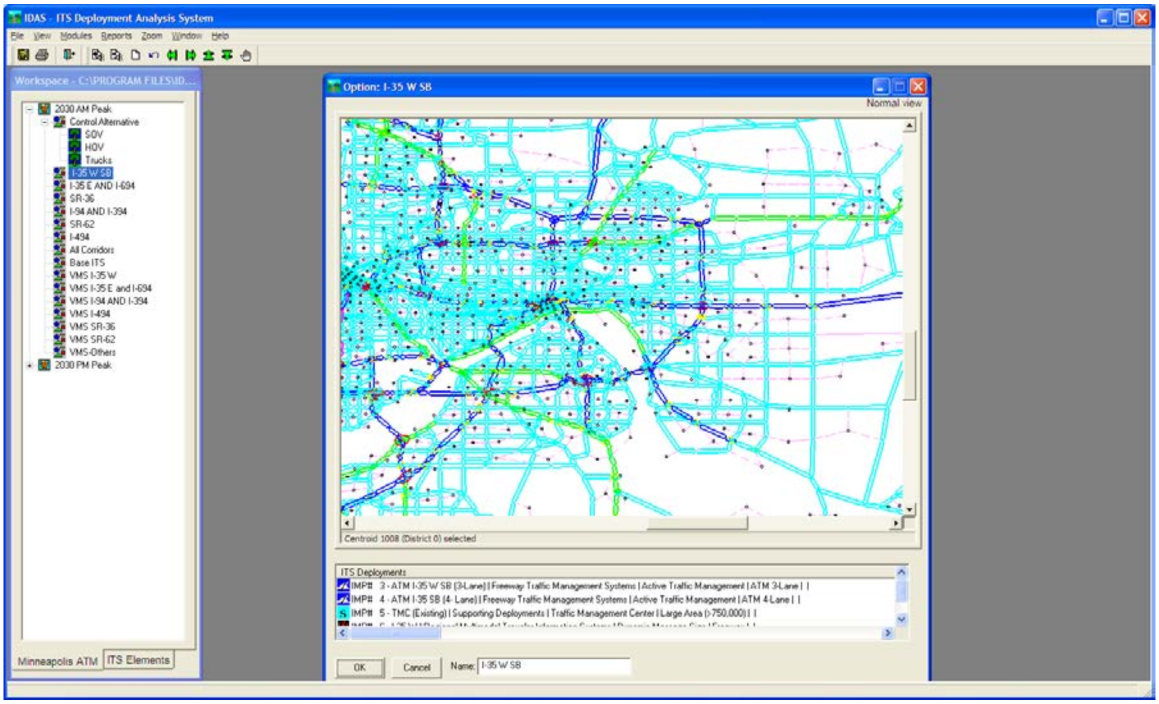


Fig 2: Screenshot of Minneapolis-St. Paul network in IDAS

2.3. Cost-Benefit Analysis

The first step in the analysis process using IDAS is to run trip assignment again for each of the alternatives. When trip assignment is done in IDAS it redistributes trips on the network based on the ITS elements deployed on the network for the alternative. Once trip assignment is run it computes the difference in values for the various measures such as vehicle miles of travel (VMT), vehicle hours of travel (VHT), average speed, number of person trips etc. Using these measures it computes the dollar value for the improvement in the performance measures of the network with the ITS improvement compared to the base case. The benefits values are annualized and total of all these benefits values is the “Total Annual Benefits”. Similarly during the analysis process the capital costs and the operations and maintenance (O& M) costs for the ITS equipment deployed are computed and annualized. This is reported as the “Total Annual Cost”. In order to compare between the various alternatives IDAS provides the values for the “Net Benefits” (Total Annual Benefits – Total Annual Costs) and the benefit to cost ratio.
It should be noted that for most analysis these measures are comparative only as they provide the relative performance of one alternative over the other. This is due to the fact that not all benefits measures are selected when running the benefits module. Again, the cost values are also highly dependent on how accurately the capital costs, the O&M costs and the life of the equipment is built into the model. The results of the AM peak analysis and PM peak analysis are provided in Table1 and Table 2 respectively.

Benefit/Cost Summary Project: Minneapolis ATM		-	-	-	-	-	-	-	-
Benefits are reported in 2010 dollars		2030 AM Peak							
Annual Benefits	Weight	Control Alternative	I-35 W SB	I-35 E AND I-694	TH-36	I-94 AND I-394	TH-62	I-494	All Corridors
Change in User Mobility	1.00	$0	$35,333,095	$26,515,731	$17,535,947	$27,760,768	$17,799,622	$26,031,302	$260,833,633
Change In User Travel Time									
In-Vehicle Travel Time	1.00	$0	$0	$0	$0	$0	$0	$0	$0
Out-of-Vehicle Travel Time	1.00	$0	$0	$0	$0	$0	$0	$0	$0
Travel Time Reliability	1.00	$0	$2,148,967	$570,239	$99,040	$549,182	-$307,143	$1,885,612	$4,420,536
Change in Costs Paid by Users									
Fuel Costs	1.00	$0	$0	$0	$0	$0	$0	$0	$0
Non-fuel Operating Costs	1.00	$0	-$58,072	$12,694	$44,136	-$34,396	-$2,733	-$74,352	-$3,949
Accident Costs (Internal Only)	1.00	$0	$1,393,955	$796,582	$319,497	$2,100,570	$385,084	$1,367,085	$6,416,994
Change in External Costs									
Accident Costs (External Only)	1.00	$0	$245,994	$140,574	$56,382	$370,692	$67,956	$241,252	$1,132,418
Emissions									
HC/ROG	1.00	$0	$0	$0	$0	$0	$0	$0	$0
NOx	1.00	$0	$0	$0	$0	$0	$0	$0	$0
CO	1.00	$0	$0	$0	$0	$0	$0	$0	$0
PM10	1.00	$0	$0	$0	$0	$0	$0	$0	$0
CO2	1.00	$0	$0	$0	$0	$0	$0	$0	$0
SO2	1.00	$0	$0	$0	$0	$0	$0	$0	$0
Global Warming	0.00	$0	$0	$0	$0	$0	$0	$0	$0
Noise	1.00	$0	-$600	$176	$503	-$342	$0	-$768	$18
Other Mileage-Based External Costs	1.00	$0	$0	$0	$0	$0	$0	$0	$0
Other Trip-Based External Costs	1.00	$0	$0	$0	$0	$0	$0	$0	$0
Change in Public Agencies Costs (Efficiency Induced)	1.00	$0	$0	$0	$0	$0	$0	$0	$0
Other Calculated Benefits	1.00	$0	$0	$0	$0	$0	$0	$0	$0
User Defined Additional Benefits	1.00	$0	$0	$0	$0	$0	$0	$0	$0
Total Annual Benefits		**$0**	**$39,063,339**	**$28,035,996**	**$18,055,504**	**$30,746,474**	**$17,942,786**	**$29,450,133**	**$272,799,650**
Annual Costs									
Average Annual Private Sector Cost		$0	$0	$0	$0	$0	$0	$0	$0
Average Annual Public Sector Cost		$0	$2,532,945	$1,818,215	$1,053,356	$4,514,078	$1,053,356	$2,194,460	$13,166,409
Total Annual Cost		**$0**	**$2,532,945**	**$1,818,215**	**$1,053,356**	**$4,514,078**	**$1,053,356**	**$2,194,460**	**$13,166,409**
Benefit/Cost Comparison									
Net Benefit (Annual Benefit - Annual Cost)		**$0**	**$36,530,394**	**$26,217,781**	**$17,002,149**	**$26,232,396**	**$16,889,430**	**$27,255,673**	**$259,633,241**
B/C Ratio (Annual Benefit/Annual Cost)		**0.00**	**15.42**	**15.42**	**17.14**	**6.81**	**17.03**	**13.42**	**20.72**

Table 1: 2030 AM Peak Benefit-Cost Analysis Summary.

Benefit/Cost Summary Project: Minneapolis ATM		-	-	-	-	-	-	-	-
Benefits are reported in 2010 dollars		2030 PM Peak							
Annual Benefits	Weight	Control Alternative	I-35 W SB	I-35 E AND I-694	TH-36	I-94 AND I-394	TH-62	I-494	All Corridors
Change in User Mobility	1.00	$0	$118,787,138	$95,348,403	$61,336,862	$113,706,008	$63,053,771	$91,527,922	$980,219,378
Change In User Travel Time									
In-Vehicle Travel Time	1.00	$0	$0	$0	$0	$0	$0	$0	$0
Out-of-Vehicle Travel Time	1.00	$0	$0	$0	$0	$0	$0	$0	$0
Travel Time Reliability	1.00	$0	$1,580,325	$3,837,408	$780,064	$260,424	$413,271	$1,893,631	$9,359,812
Change in Costs Paid by Users									
Fuel Costs	1.00	$0	$0	$0	$0	$0	$0	$0	$0
Non-fuel Operating Costs	1.00	$0	-$51,683	$15,057	$8,604	-$33,219	$40,815	$24,838	-$155,344
Accident Costs (Internal Only)	1.00	$0	$5,368,341	$3,563,197	$1,381,934	$8,811,806	$1,637,004	$4,725,171	$24,859,612
Change in External Costs									
Accident Costs (External Only)	1.00	$0	$947,361	$628,803	$243,872	$1,555,035	$288,885	$833,858	$4,387,018
Emissions									
HC/ROG	1.00	$0	$0	$0	$0	$0	$0	$0	$0
NOx	1.00	$0	$0	$0	$0	$0	$0	$0	$0
CO	1.00	$0	$0	$0	$0	$0	$0	$0	$0
PM10	1.00	$0	$0	$0	$0	$0	$0	$0	$0
CO2	1.00	$0	$0	$0	$0	$0	$0	$0	$0
SO2	1.00	$0	$0	$0	$0	$0	$0	$0	$0
Global Warming	0.00	$0	$0	$0	$0	$0	$0	$0	$0
Noise	1.00	$0	-$551	$168	$108	-$341	$447	$265	-$1,630
Other Mileage-Based External Costs	1.00	$0	$0	$0	$0	$0	$0	$0	$0
Other Trip-Based External Costs	1.00	$0	$0	$0	$0	$0	$0	$0	$0
Change in Public Agencies Costs (Efficiency Induced)	1.00	$0	$0	$0	$0	$0	$0	$0	$0
Other Calculated Benefits	1.00	$0	$0	$0	$0	$0	$0	$0	$0
User Defined Additional Benefits	1.00	$0	$0	$0	$0	$0	$0	$0	$0
Total Annual Benefits		**$0**	**$126,630,931**	**$103,393,036**	**$63,751,444**	**$124,299,713**	**$65,434,193**	**$99,005,685**	**$1,018,668,846**
Annual Costs									
Average Annual Private Sector Cost		$0	$0	$0	$0	$0	$0	$0	$0
Average Annual Public Sector Cost		$0	$2,532,945	$1,818,215	$1,053,356	$4,514,078	$1,053,356	$2,194,460	$13,166,409
Total Annual Cost		**$0**	**$2,532,945**	**$1,818,215**	**$1,053,356**	**$4,514,078**	**$1,053,356**	**$2,194,460**	**$13,166,409**
Benefit/Cost Comparison									
Net Benefit (Annual Benefit - Annual Cost)		**$0**	**$124,097,986**	**$101,574,821**	**$62,698,088**	**$119,785,635**	**$64,380,837**	**$96,811,225**	**$1,005,502,437**
B/C Ratio (Annual Benefit/Annual Cost)		**0.00**	**49.99**	**56.87**	**60.52**	**27.54**	**62.12**	**45.12**	**77.37**

Table 2: 2030 PM Peak Benefit-Cost Analysis Summary.

3. Results & Conclusion

Looking at the benefit cost summary for both the AM peak period and the PM peak period we see that the highest benefit to cost ratio and net benefits is for implementing speed harmonization/lane control system on all the identified corridors. This means that investment in deploying the ATM system on the corridors would yield benefits for the metropolitan highway system and help improve the operation of the system. The results of the analysis for each corridor help develop the strategy for systematic deployment on the network. If we rank order the corridors based on the benefit-cost ratio for each of the periods we get the following ranked list.

Corridor	B/C Ratio	Rank
AM Peak		
TH-36	17.14	1
TH-62	17.03	2
I-35 W SB	15.42	3
I-35 E AND I-694	15.42	4
I-494	13.42	5
I-94 AND I-394	6.81	6
PM Peak		
TH-62	62.12	1
TH-36	60.52	2
I-35 E AND I-694	56.87	3
I-35 W SB	49.99	4
I-494	45.12	5
I-94 AND I-394	27.54	6

Table 3: Corridors rank ordered by benefit cost ratio

As we see from the results the TH-36 and TH-62 corridors provide have the highest benefit-to-cost ratio and should be the first corridors in which the system should be deployed. More complex decision models can also be employed to select alternatives that are based on specific goals. Appendix B provides the values of the risk analysis performed for each alternative. The risk analysis results can also be used for developing a deployment strategy.

In a nutshell it can be said that the results of the analysis prove that ATM deployment on the corridors would provide an efficient means of managing these corridors and would prove to be an efficient and cost effective strategy. ATM also enables the agencies in the region make best use of their existing ITS infrastructure. As such ATM should be an integral part of any transportation plan for the region.

APPENDIX A
AM PEAK RESULTS BY MARKET SECTOR

ATM Deployment Scenario	By: Market Sector	SOV	HOV	Trucks	Total
	Vehicle Miles of Travel				
	Control Alternative	11,073,304	3,689	456,701	11,533,694
I-35 W SB	ITS Option	11,074,882	3,679	456,772	11,535,334
	Difference (%)	1,578(0.0%)	-9(-0.3%)	71(0.0%)	1,640(0.0%)
I-35 E AND I-694	ITS Option	11,072,781	3,673	456,734	11,533,189
	Difference (%)	-523(0.0%)	-15(-0.4%)	33(0.0%)	-505(0.0%)
TH-36	ITS Option	11,071,921	3,677	456,698	11,532,296
	Difference (%)	-1,383(0.0%)	-11(-0.3%)	-4(0.0%)	-1,398(0.0%)
I-94 AND I-394	ITS Option	11,074,186	3,678	456,758	11,534,621
	Difference (%)	882(0.0%)	-11(-0.3%)	57(0.0%)	928(0.0%)
TH-62	ITS Option	11,073,275	3,671	456,735	11,533,680
	Difference (%)	-29(0.0%)	-18(-0.5%)	33(0.0%)	-14(0.0%)
I-494	ITS Option	11,075,310	3,689	456,793	11,535,792
	Difference (%)	2,006(0.0%)	0(0.0%)	92(0.0%)	2,098(0.0%)
ALL CORRIDORS	ITS Option	11,073,174	3,671	456,769	11,533,614
	Difference (%)	-130(0.0%)	-18(-0.5%)	68(0.0%)	-80(0.0%)
	Vehicle Hours of Travel				
	Control Alternative	463,974	158	16,321	480,452
I-35 W SB	ITS Option	463,941	158	16,322	480,421
	Difference (%)	-33(0.0%)	0(0.1%)	1(0.0%)	-32(0.0%)
I-35 E AND I-694	ITS Option	463,902	158	16,317	480,377
	Difference (%)	-73(0.0%)	0(0.1%)	-3(0.0%)	-76(0.0%)
TH-36	ITS Option	463,957	158	16,322	480,436
	Difference (%)	-18(0.0%)	0(0.1%)	1(0.0%)	-17(0.0%)
I-94 AND I-394	ITS Option	464,062	158	16,323	480,543
	Difference (%)	88(0.0%)	0(0.2%)	2(0.0%)	90(0.0%)
TH-62	ITS Option	463,946	158	16,320	480,424
	Difference (%)	-28(0.0%)	0(0.1%)	-1(0.0%)	-29(0.0%)
I-494	ITS Option	464,009	158	16,322	480,489
	Difference (%)	35(0.0%)	0(0.2%)	1(0.0%)	37(0.0%)
ALL CORRIDORS	ITS Option	463,740	158	16,311	480,208
	Difference (%)	-234(-0.1%)	0(0.2%)	-10(-0.1%)	-244(-0.1%)
	Average Speed				
	Control Alternative	23.9	23.4	28.0	24.0
I-35 W	ITS Option	23.9	23.3	28.0	24.0

SB	Difference (%)	0(0.0%)	0(-0.4%)	0(0.0%)	0(0.0%)
I-35 E AND I-694	ITS Option	24	23	28	24
	Difference (%)	0(0.0%)	0(-0.5%)	0(0.0%)	0(0.0%)
TH-36	ITS Option	24	23	28	24
	Difference (%)	0(0.0%)	0(-0.4%)	0(0.0%)	0(0.0%)
I-94 AND I-394	ITS Option	24	23	28	24
	Difference (%)	0(0.0%)	0(-0.5%)	0(0.0%)	0(0.0%)
TH-62	ITS Option	24	23	28	24
	Difference (%)	0(0.0%)	0(-0.6%)	0(0.0%)	0(0.0%)
I-494	ITS Option	24	23	28	24
	Difference (%)	0(0.0%)	0(-0.2%)	0(0.0%)	0(0.0%)
ALL CORRIDORS	ITS Option	24	23	28	24
	Difference (%)	0(0.0%)	0(-0.7%)	0(0.1%)	0(0.0%)
	Person Hours of Travel				
	Control Alternative	463,974	158	16,321	480,452
I-35 W SB	ITS Option	658,796	432	25,788	685,017
	Difference (%)	-47(0.0%)	1(0.1%)	2(0.0%)	-44(0.0%)
I-35 E AND I-694	ITS Option	658,740	432	25,782	684,954
	Difference (%)	-103(0.0%)	0(0.1%)	-5(0.0%)	-108(0.0%)
TH-36	ITS Option	658,818	432	25,788	685,039
	Difference (%)	-25(0.0%)	1(0.1%)	1(0.0%)	-23(0.0%)
I-94 AND I-394	ITS Option	658,968	432	25,790	685,191
	Difference (%)	125(0.0%)	1(0.2%)	3(0.0%)	129(0.0%)
TH-62	ITS Option	658,803	432	25,786	685,021
	Difference (%)	-40(0.0%)	0(0.1%)	-1(0.0%)	-41(0.0%)
I-494	ITS Option	658,893	432	25,789	685,114
	Difference (%)	50(0.0%)	1(0.2%)	2(0.0%)	53(0.0%)
ALL CORRIDORS	ITS Option	658,510	432	25,771	684,714
	Difference (%)	-333(-0.1%)	1(0.2%)	-16(-0.1%)	-348(-0.1%)
	Number of Person Trips				
	Control Alternative	1,993,774	444	113,536	2,107,754
I-35 W SB	ITS Option	1,993,774	444	113,536	2,107,754
	Difference (%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)
I-35 E AND I-694	ITS Option	1,993,774	444	113,536	2,107,754
	Difference (%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)
TH-36	ITS Option	1,993,774	444	113,536	2,107,754
	Difference (%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)
I-94 AND I-394	ITS Option	1,993,774	444	113,536	2,107,754
	Difference (%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)
TH-62	ITS Option	1,993,774	444	113,536	2,107,754
	Difference (%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)
I-494	ITS Option	1,993,774	444	113,536	2,107,754
	Difference (%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)

ALL CORRIDORS	ITS Option	1,993,774	444	113,536	2,107,754
	Difference (%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)
	Number of Fatality Accidents				
	Control Alternative	1.3234E-01	2.6652E-05	5.3117E-03	1.3768E-01
I-35 W SB	ITS Option	1.1882E-01	2.4199E-05	4.7709E-03	1.2362E-01
	Difference (%)	-3.974E-04(-0.3%)	-2.004E-07(-0.8%)	-2.554E-05(-0.5%)	-4.231E-04(-0.3%)
I-35 E AND I-694	ITS Option	1.1898E-01	2.4171E-05	4.7818E-03	1.2379E-01
	Difference (%)	-2.336E-04(-0.2%)	-2.292E-07(-0.9%)	-1.466E-05(-0.3%)	-2.485E-04(-0.2%)
TH-36	ITS Option	1.1913E-01	2.4178E-05	4.7868E-03	1.2394E-01
	Difference (%)	-8.603E-05(-0.1%)	-2.215E-07(-0.9%)	-9.725E-06(-0.2%)	-9.598E-05(-0.1%)
I-94 AND I-394	ITS Option	1.1860E-01	2.4241E-05	4.7507E-03	1.2338E-01
	Difference (%)	-6.159E-04(-0.5%)	-1.593E-07(-0.7%)	-4.576E-05(-1.0%)	-6.618E-04(-0.5%)
TH-62	ITS Option	1.1911E-01	2.4114E-05	4.7853E-03	1.2392E-01
	Difference (%)	-1.094E-04(-0.1%)	-2.859E-07(-1.2%)	-1.116E-05(-0.2%)	-1.209E-04(-0.1%)
I-494	ITS Option	1.1882E-01	2.4120E-05	4.7751E-03	1.2361E-01
	Difference (%)	-4.031E-04(-0.3%)	-2.799E-07(-1.1%)	-2.141E-05(-0.4%)	-4.248E-04(-0.3%)
ALL CORRIDORS	ITS Option	1.1736E-01	2.3897E-05	4.6665E-03	1.2205E-01
	Difference (%)	-1.858E-03(-1.6%)	-5.031E-07(-2.1%)	-1.3E-04(-2.7%)	-1.989E-03(-1.6%)
	Number of Injury Accidents				
	Control Alternative	1.2277E+01	2.4198E-03	4.9164E-01	1.2771E+01
I-35 W SB	ITS Option	1.0874E+01	2.1728E-03	4.3480E-01	1.1311E+01
	Difference (%)	-3.093E-02(-0.3%)	-1.778E-05(-0.8%)	-1.967E-03(-0.5%)	-3.291E-02(-0.3%)
I-35 E AND I-694	ITS Option	1.0888E+01	2.1696E-03	4.3569E-01	1.1326E+01
	Difference (%)	-1.738E-02(-0.2%)	-2.096E-05(-1.0%)	-1.078E-03(-0.2%)	-1.848E-02(-0.2%)
TH-36	ITS Option	1.0898E+01	2.1716E-03	4.3605E-01	1.1337E+01
	Difference (%)	-6.754E-03(-0.1%)	-1.9E-05(-0.9%)	-7.201E-04(-0.2%)	-7.493E-03(-0.1%)
I-94 AND I-394	ITS Option	1.0860E+01	2.1761E-03	4.3342E-01	1.1296E+01
	Difference (%)	-4.521E-02(-0.4%)	-1.448E-05(-0.7%)	-3.351E-03(-0.8%)	-4.858E-02(-0.4%)
TH-62	ITS Option	1.0897E+01	2.1660E-03	4.3595E-01	1.1335E+01
	Difference (%)	-8.039E-03(-0.1%)	-2.454E-05(-1.1%)	-8.211E-04(-0.2%)	-8.885E-03(-0.1%)
I-494	ITS Option	1.0875E+01	2.1692E-03	4.3521E-01	1.1312E+01
	Difference (%)	-3.03E-02(-0.3%)	-2.135E-05(-1.0%)	-1.556E-03(-0.4%)	-3.187E-02(-0.3%)
ALL CORRIDORS	ITS Option	1.0765E+01	2.1477E-03	4.2703E-01	1.1195E+01
	Difference (%)	-1.398E-01(-1.3%)	-4.284E-05(-2.0%)	-9.737E-03(-2.2%)	-1.495E-01(-1.3%)
	Number of PDO Accidents				
	Control Alternative	1.7613E+01	3.3948E-03	7.0371E-01	1.8320E+01
I-35 W SB	ITS Option	1.5498E+01	3.0204E-03	6.1881E-01	1.6120E+01
	Difference (%)	-2.108E-02(-0.1%)	-2.373E-05(-0.8%)	-1.317E-03(-0.2%)	-2.242E-02(-0.1%)
I-35 E	ITS Option	1.5507E+01	3.0143E-03	6.1943E-01	1.6129E+01

AND I-694	Difference (%)	-1.248E-02(-0.1%)	-2.983E-05(-1.0%)	-6.977E-04(-0.1%)	-1.321E-02(-0.1%)
TH-36	ITS Option	1.5513E+01	3.0162E-03	6.1963E-01	1.6135E+01
	Difference (%)	-6.353E-03(0.0%)	-2.799E-05(-0.9%)	-5.007E-04(-0.1%)	-6.882E-03(0.0%)
I-94 AND I-394	ITS Option	1.5489E+01	3.0253E-03	6.1795E-01	1.6110E+01
	Difference (%)	-3.014E-02(-0.2%)	-1.883E-05(-0.6%)	-2.18E-03(-0.4%)	-3.234E-02(-0.2%)
TH-62	ITS Option	1.5513E+01	3.0100E-03	6.1956E-01	1.6136E+01
	Difference (%)	-6.044E-03(0.0%)	-3.412E-05(-1.1%)	-5.704E-04(-0.1%)	-6.649E-03(0.0%)
I-494	ITS Option	1.5499E+01	3.0254E-03	6.1910E-01	1.6121E+01
	Difference (%)	-2.02E-02(-0.1%)	-1.872E-05(-0.6%)	-1.03E-03(-0.2%)	-2.125E-02(-0.1%)
ALL CORRIDORS	ITS Option	1.5420E+01	2.9979E-03	6.1346E-01	1.6037E+01
	Difference (%)	-9.868E-02(-0.6%)	-4.629E-05(-1.5%)	-6.665E-03(-1.1%)	-1.054E-01(-0.7%)
	Travel Time Reliability (hours of unexpected delay)				
	Control Alternative	6,383.87	8.04	122.69	6,514.60
I-35 W SB	ITS Option	13,539.31	10.89	270.10	13,820.29
	Difference (%)	-140.01(-1.0%)	-0.12(-1.1%)	-2.66(-1.0%)	-142.79(-1.0%)
I-35 E AND I-694	ITS Option	13,643.00	10.98	271.58	13,925.55
	Difference (%)	-36.31(-0.3%)	-0.03(-0.3%)	-1.18(-0.4%)	-37.53(-0.3%)
TH-36	ITS Option	13,672.84	11.10	272.59	13,956.53
	Difference (%)	-6.47(0.0%)	0.10(0.9%)	-0.17(-0.1%)	-6.55(0.0%)
I-94 AND I-394	ITS Option	13,643.79	10.93	271.96	13,926.68
	Difference (%)	-35.52(-0.3%)	-0.08(-0.7%)	-0.80(-0.3%)	-36.40(-0.3%)
TH-62	ITS Option	13,699.86	11.05	272.82	13,983.73
	Difference (%)	20.55(0.2%)	0.05(0.4%)	0.06(0.0%)	20.65(0.1%)
I-494	ITS Option	13,558.30	10.90	269.38	13,838.59
	Difference (%)	-121.01(-0.9%)	-0.11(-1.0%)	-3.38(-1.2%)	-124.49(-0.9%)
ALL CORRIDORS	ITS Option	13,394.41	10.78	265.52	13,670.71
	Difference (%)	-284.91(-2.1%)	-0.22(-2.0%)	-7.24(-2.7%)	-292.37(-2.1%)

APPENDIX B
PM PEAK RESULTS BY MARKET SECTOR

ATM Deployment Scenario	By: Market Sector	SOV	HOV	Trucks	Total
	Vehicle Miles of Travel				
	Control Alternative	28,499,674	5,209	654,578	29,159,461
I-35 W SB	ITS Option	28,501,146	5,209	654,622	29,160,977
	Difference (%)	1,472(0.0%)	1(0.0%)	44(0.0%)	1,517(0.0%)
I-35 E AND I-694	ITS Option	28,499,220	5,206	654,572	29,158,998
	Difference (%)	-454(0.0%)	-3(-0.1%)	-6(0.0%)	-463(0.0%)
TH-36	ITS Option	28,499,362	5,209	654,587	29,159,158
	Difference (%)	-312(0.0%)	0(0.0%)	9(0.0%)	-303(0.0%)
I-94 AND I-394	ITS Option	28,500,566	5,206	654,621	29,160,392
	Difference (%)	892(0.0%)	-3(-0.1%)	43(0.0%)	932(0.0%)
TH-62	ITS Option	28,498,466	5,207	654,555	29,158,228
	Difference (%)	-1,208(0.0%)	-2(0.0%)	-23(0.0%)	-1,233(0.0%)
I-494	ITS Option	28,498,966	5,209	654,557	29,158,732
	Difference (%)	-708(0.0%)	0(0.0%)	-21(0.0%)	-729(0.0%)
ALL CORRIDORS	ITS Option	28,503,974	5,211	654,742	29,163,927
	Difference (%)	4,300(0.0%)	3(0.1%)	164(0.0%)	4,466(0.0%)
	Vehicle Hours of Travel				
	Control Alternative	774,267	136	20,145	794,548
I-35 W SB	ITS Option	774,119	136	20,140	794,395
	Difference (%)	-148(0.0%)	0(0.0%)	-5(0.0%)	-153(0.0%)
I-35 E AND I-694	ITS Option	774,014	136	20,138	794,289
	Difference (%)	-253(0.0%)	0(-0.1%)	-7(0.0%)	-259(0.0%)
TH-36	ITS Option	774,125	136	20,140	794,401
	Difference (%)	-142(0.0%)	0(0.0%)	-5(0.0%)	-147(0.0%)
I-94 AND I-394	ITS Option	774,154	136	20,143	794,433
	Difference (%)	-113(0.0%)	0(0.0%)	-3(0.0%)	-115(0.0%)
TH-62	ITS Option	774,062	136	20,139	794,337
	Difference (%)	-204(0.0%)	0(0.0%)	-7(0.0%)	-211(0.0%)
I-494	ITS Option	773,982	136	20,138	794,255
	Difference (%)	-285(0.0%)	0(0.0%)	-7(0.0%)	-293(0.0%)
ALL CORRIDORS	ITS Option	773,455	136	20,123	793,714
	Difference (%)	-812(-0.1%)	0(-0.1%)	-22(-0.1%)	-834(-0.1%)
	Average Speed				
	Control Alternative	36.8	38.3	32.5	36.7
I-35 W	ITS Option	36.8	38.3	32.5	36.7

SB	Difference (%)	0(0.0%)	0(0.1%)	0(0.0%)	0(0.0%)
I-35 E AND I-694	ITS Option	36.8	38.3	32.5	36.7
	Difference (%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)
TH-36	ITS Option	36.8	38.3	32.5	36.7
	Difference (%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)
I-94 AND I-394	ITS Option	36.8	38.3	32.5	36.7
	Difference (%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)
TH-62	ITS Option	36.8	38.3	32.5	36.7
	Difference (%)	0(0.0%)	0(-0.1%)	0(0.0%)	0(0.0%)
I-494	ITS Option	36.8	38.3	32.5	36.7
	Difference (%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)
ALL CORRIDORS	ITS Option	36.9	38.4	32.5	36.7
	Difference (%)	0(0.1%)	0(0.1%)	0(0.1%)	0(0.0%)
	Person Hours of Travel				
	Control Alternative	1,099,459	372	31,829	1,131,661
I-35 W SB	ITS Option	1,099,248	372	31,822	1,131,442
	Difference (%)	-211(0.0%)	0(0.0%)	-8(0.0%)	-218(0.0%)
I-35 E AND I-694	ITS Option	1,099,100	372	31,819	1,131,291
	Difference (%)	-359(0.0%)	0(-0.1%)	-11(0.0%)	-370(0.0%)
TH-36	ITS Option	1,099,257	372	31,821	1,131,451
	Difference (%)	-202(0.0%)	0(0.0%)	-8(0.0%)	-210(0.0%)
I-94 AND I-394	ITS Option	1,099,299	372	31,825	1,131,497
	Difference (%)	-160(0.0%)	0(0.0%)	-4(0.0%)	-164(0.0%)
TH-62	ITS Option	1,099,169	372	31,819	1,131,360
	Difference (%)	-290(0.0%)	0(0.0%)	-10(0.0%)	-301(0.0%)
I-494	ITS Option	1,099,054	372	31,817	1,131,244
	Difference (%)	-405(0.0%)	0(0.0%)	-12(0.0%)	-417(0.0%)
ALL CORRIDORS	ITS Option	1,098,306	372	31,795	1,130,473
	Difference (%)	-1,153(-0.1%)	0(-0.1%)	-35(-0.1%)	-1,188(-0.1%)
	Number of Person Trips				
	Control Alternative	4,574,629	775	172,127	4,747,531
I-35 W SB	ITS Option	4,574,629	775	172,127	4,747,531
	Difference (%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)
I-35 E AND I-694	ITS Option	4,574,629	775	172,127	4,747,531
	Difference (%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)
TH-36	ITS Option	4,574,629	775	172,127	4,747,531
	Difference (%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)
I-94 AND I-394	ITS Option	4,574,629	775	172,127	4,747,531
	Difference (%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)
TH-62	ITS Option	4,574,629	775	172,127	4,747,531
	Difference (%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)
I-494	ITS Option	4,574,629	775	172,127	4,747,531
	Difference (%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)

ALL CORRIDORS	ITS Option	4,574,629	775	172,127	4,747,531
	Difference (%)	0(0.0%)	0(0.0%)	0(0.0%)	0(0.0%)
	Number of Fatality Accidents				
	Control Alternative	2.9392E-01	4.0276E-05	6.9436E-03	3.0091E-01
I-35 W SB	ITS Option	2.9228E-01	3.8071E-05	6.9039E-03	2.9923E-01
	Difference (%)	-1.64E-03(-0.6%)	-2.205E-06(-5.5%)	-3.972E-05(-0.6%)	-1.682E-03(-0.6%)
I-35 E AND I-694	ITS Option	2.9286E-01	4.0244E-05	6.9213E-03	2.9982E-01
	Difference (%)	-1.067E-03(-0.4%)	-3.273E-08(-0.1%)	-2.232E-05(-0.3%)	-1.09E-03(-0.4%)
TH-36	ITS Option	2.9352E-01	4.0250E-05	6.9284E-03	3.0048E-01
	Difference (%)	-4.091E-04(-0.1%)	-2.65E-08(-0.1%)	-1.52E-05(-0.2%)	-4.244E-04(-0.1%)
I-94 AND I-394	ITS Option	2.9121E-01	4.0172E-05	6.8756E-03	2.9812E-01
	Difference (%)	-2.719E-03(-0.9%)	-1.043E-07(-0.3%)	-6.806E-05(-1.0%)	-2.787E-03(-0.9%)
TH-62	ITS Option	2.9343E-01	4.0051E-05	6.9273E-03	3.0040E-01
	Difference (%)	-4.91E-04(-0.2%)	-2.253E-07(-0.6%)	-1.637E-05(-0.2%)	-5.076E-04(-0.2%)
I-494	ITS Option	2.9250E-01	3.9220E-05	6.9093E-03	2.9945E-01
	Difference (%)	-1.428E-03(-0.5%)	-1.057E-06(-2.6%)	-3.43E-05(-0.5%)	-1.463E-03(-0.5%)
ALL CORRIDORS	ITS Option	2.8632E-01	3.6852E-05	6.7491E-03	2.9310E-01
	Difference (%)	-7.607E-03(-2.6%)	-3.424E-06(-8.5%)	-1.945E-04(-2.8%)	-7.805E-03(-2.6%)
	Number of Injury Accidents				
	Control Alternative	2.6162E+01	3.3475E-03	6.2588E-01	2.6791E+01
I-35 W SB	ITS Option	2.6041E+01	3.1872E-03	6.2297E-01	2.6667E+01
	Difference (%)	-1.212E-01(-0.5%)	-1.603E-04(-4.8%)	-2.911E-03(-0.5%)	-1.243E-01(-0.5%)
I-35 E AND I-694	ITS Option	2.6080E+01	3.3433E-03	6.2417E-01	2.6708E+01
	Difference (%)	-8.179E-02(-0.3%)	-4.171E-06(-0.1%)	-1.706E-03(-0.3%)	-8.35E-02(-0.3%)
TH-36	ITS Option	2.6131E+01	3.3444E-03	6.2474E-01	2.6759E+01
	Difference (%)	-3.11E-02(-0.1%)	-3.057E-06(-0.1%)	-1.14E-03(-0.2%)	-3.225E-02(-0.1%)
I-94 AND I-394	ITS Option	2.5964E+01	3.3386E-03	6.2091E-01	2.6588E+01
	Difference (%)	-1.98E-01(-0.8%)	-8.863E-06(-0.3%)	-4.963E-03(-0.8%)	-2.03E-01(-0.8%)
TH-62	ITS Option	2.6125E+01	3.3284E-03	6.2467E-01	2.6753E+01
	Difference (%)	-3.677E-02(-0.1%)	-1.905E-05(-0.6%)	-1.209E-03(-0.2%)	-3.8E-02(-0.1%)
I-494	ITS Option	2.6055E+01	3.2661E-03	6.2333E-01	2.6682E+01
	Difference (%)	-1.073E-01(-0.4%)	-8.134E-05(-2.4%)	-2.544E-03(-0.4%)	-1.099E-01(-0.4%)
ALL CORRIDORS	ITS Option	2.5602E+01	3.0947E-03	6.1156E-01	2.6217E+01
	Difference (%)	-5.602E-01(-2.1%)	-2.527E-04(-7.5%)	-1.431E-02(-2.3%)	-5.748E-01(-2.1%)
	Number of PDO Accidents				
	Control Alternative	3.7053E+01	4.6138E-03	8.9069E-01	3.7948E+01
I-35 W SB	ITS Option	3.6967E+01	4.5029E-03	8.8867E-01	3.7861E+01
	Difference (%)	-8.533E-02(-0.2%)	-1.109E-04(-2.4%)	-2.022E-03(-0.2%)	-8.746E-02(-0.2%)
I-35 E AND I-	ITS Option	3.6992E+01	4.6073E-03	8.8940E-01	3.7886E+01
	Difference (%)	-6.097E-	-6.483E-	-1.289E-	-6.227E-

694		02(-0.2%)	06(-0.1%)	03(-0.1%)	02(-0.2%)
TH-36	ITS Option	3.7028E+01	4.6092E-03	8.8985E-01	3.7923E+01
	Difference (%)	-2.43E-02(-0.1%)	-4.589E-06(-0.1%)	-8.416E-04(-0.1%)	-2.514E-02(-0.1%)
I-94 AND I-394	ITS Option	3.6915E+01	4.6054E-03	8.8723E-01	3.7807E+01
	Difference (%)	-1.379E-01(-0.4%)	-8.458E-06(-0.2%)	-3.459E-03(-0.4%)	-1.414E-01(-0.4%)
TH-62	ITS Option	3.7024E+01	4.5943E-03	8.8981E-01	3.7919E+01
	Difference (%)	-2.844E-02(-0.1%)	-1.955E-05(-0.4%)	-8.801E-04(-0.1%)	-2.934E-02(-0.1%)
I-494	ITS Option	3.6972E+01	4.5453E-03	8.8882E-01	3.7865E+01
	Difference (%)	-8.064E-02(-0.2%)	-6.849E-05(-1.5%)	-1.875E-03(-0.2%)	-8.259E-02(-0.2%)
ALL CORRIDORS	ITS Option	3.6656E+01	4.4308E-03	8.8055E-01	3.7541E+01
	Difference (%)	-3.965E-01(-1.1%)	-1.83E-04(-4.0%)	-1.014E-02(-1.1%)	-4.069E-01(-1.1%)
	Travel Time Reliability (hours of unexpected delay)				
	Control Alternative	7,732.28	2.00	143.97	7,878.25
I-35 W SB	ITS Option	7,629.71	1.97	141.76	7,773.44
	Difference (%)	-102.57(-1.3%)	-0.03(-1.4%)	-2.21(-1.5%)	-104.81(-1.3%)
I-35 E AND I-694	ITS Option	7,482.87	1.98	138.76	7,623.62
	Difference (%)	-249.41(-3.2%)	-0.02(-0.8%)	-5.20(-3.6%)	-254.63(-3.2%)
TH-36	ITS Option	7,682.18	1.98	142.58	7,826.74
	Difference (%)	-50.10(-0.6%)	-0.02(-0.8%)	-1.39(-1.0%)	-51.51(-0.7%)
I-94 AND I-394	ITS Option	7,715.42	1.98	143.59	7,860.98
	Difference (%)	-16.86(-0.2%)	-0.02(-1.1%)	-0.38(-0.3%)	-17.26(-0.2%)
TH-62	ITS Option	7,706.33	1.96	142.91	7,851.20
	Difference (%)	-25.95(-0.3%)	-0.03(-1.7%)	-1.06(-0.7%)	-27.05(-0.3%)
I-494	ITS Option	7,609.75	1.92	141.13	7,752.80
	Difference (%)	-122.53(-1.6%)	-0.08(-4.0%)	-2.84(-2.0%)	-125.44(-1.6%)
ALL CORRIDORS	ITS Option	7,126.24	1.88	130.02	7,258.14
	Difference (%)	-606.04(-7.8%)	-0.11(-5.7%)	-13.95(-9.7%)	-620.11(-7.9%)

APPENDIX C
RISK ANALYSIS

I-35 W SB (AM Peak)

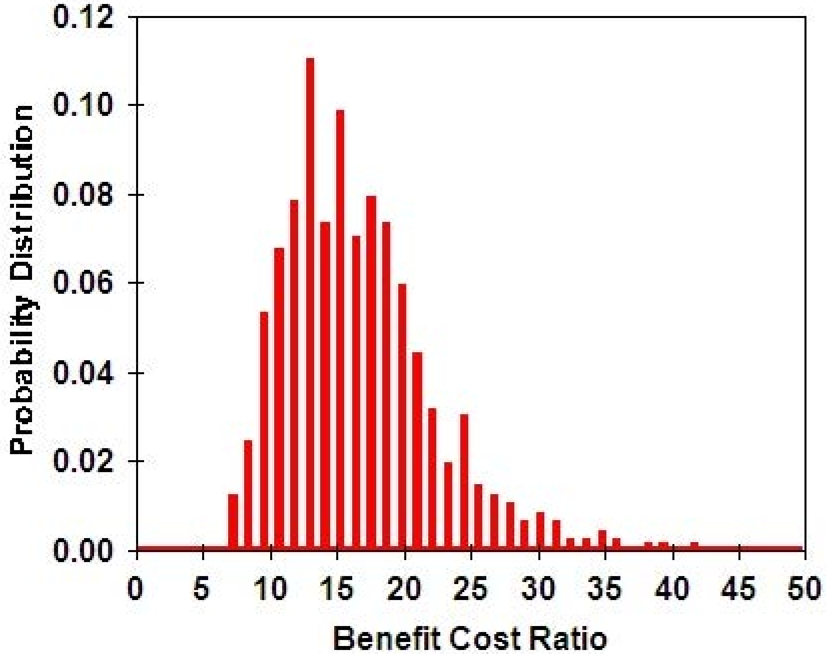


Fig **3**: Histogram for B/C ratio for I-35 W SB (AM Peak)

- Mean B/C Ratio = 16.98
- Median B/C Ratio = 16.2
- Cost-Benefit Analysis B/C Ratio = 15.42
- Confidence level that value will be greater than or equal to the Analysis Value = 60%

I-35 E And I-694 (AM Peak)

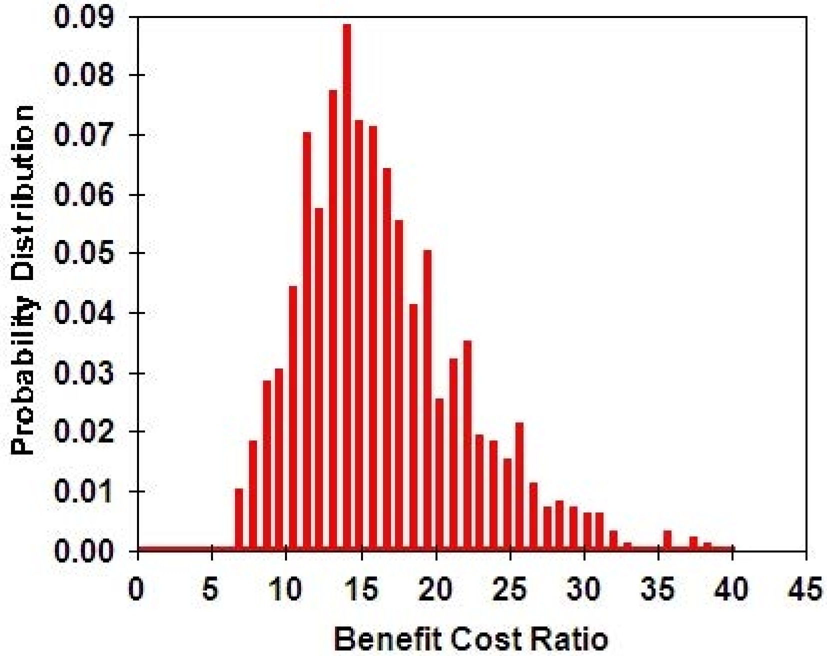


Fig 4: Histogram for B/C ratio for I-35E And I-694 (AM Peak)

- Mean B/C Ratio = 16.83
- Median B/C Ratio = 15.9
- Cost-Benefit Analysis B/C Ratio = 15.42
- Confidence level that value will be greater than or equal to the Analysis Value = 60%

TH-36 (AM Peak)

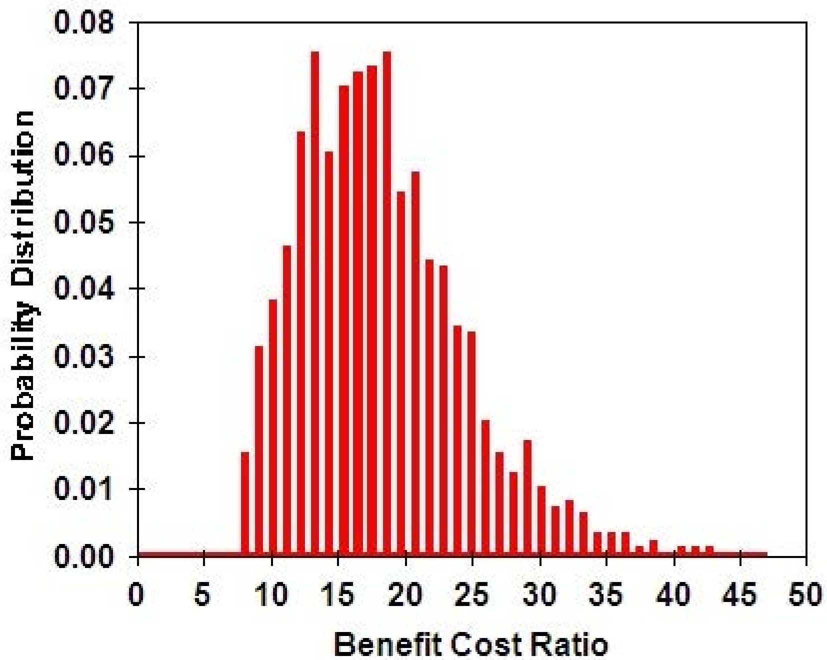


Fig 5: Histogram for B/C ratio for I-35E And I-694 (AM Peak)

- Mean B/C Ratio = 18.63
- Median B/C Ratio = 17.97
- Cost-Benefit Analysis B/C Ratio = 17.14
- Confidence level that value will be greater than or equal to the Analysis Value = 60%

I-94 And I-394 (AM Peak)

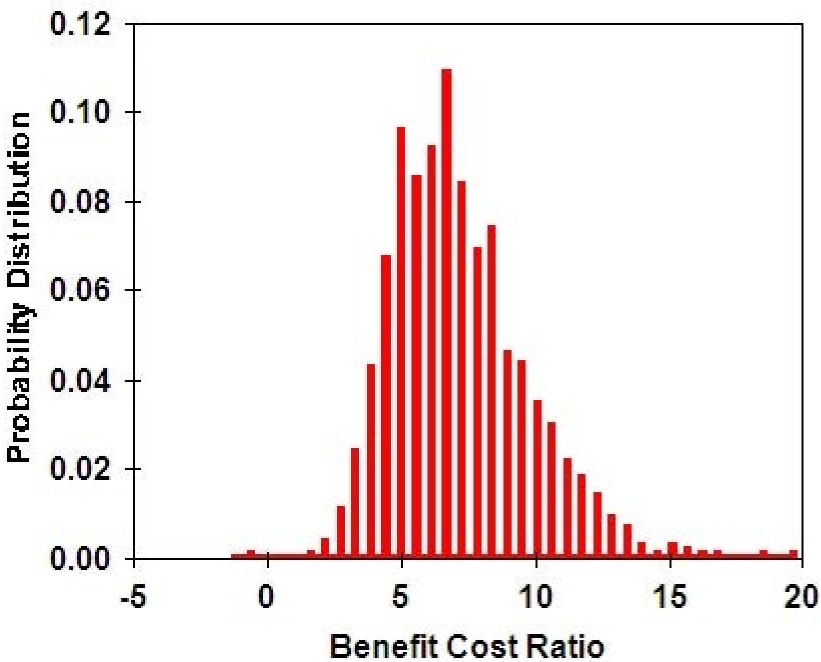


Fig 6: Histogram for B/C ratio for I-94 and I-394 (AM Peak)

- Mean B/C Ratio = 7.45
- Median B/C Ratio = 7.06
- Cost-Benefit Analysis B/C Ratio = 6.81
- Confidence level that value will be greater than or equal to the Analysis Value = 60%

TH-62 (AM Peak)

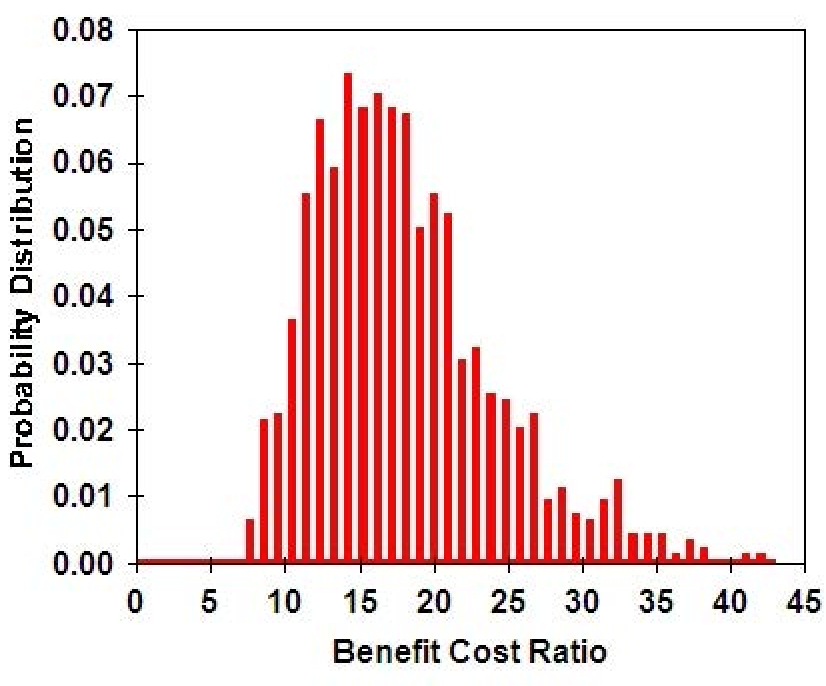


Fig 7: Histogram for B/C ratio for TH-62 (AM Peak)

- Mean B/C Ratio = 18.41

- Median B/C Ratio = 17.41
- Cost-Benefit Analysis B/C Ratio = 17.03
- Confidence level that value will be greater than or equal to the Analysis Value = 60%

I-494 (AM Peak)

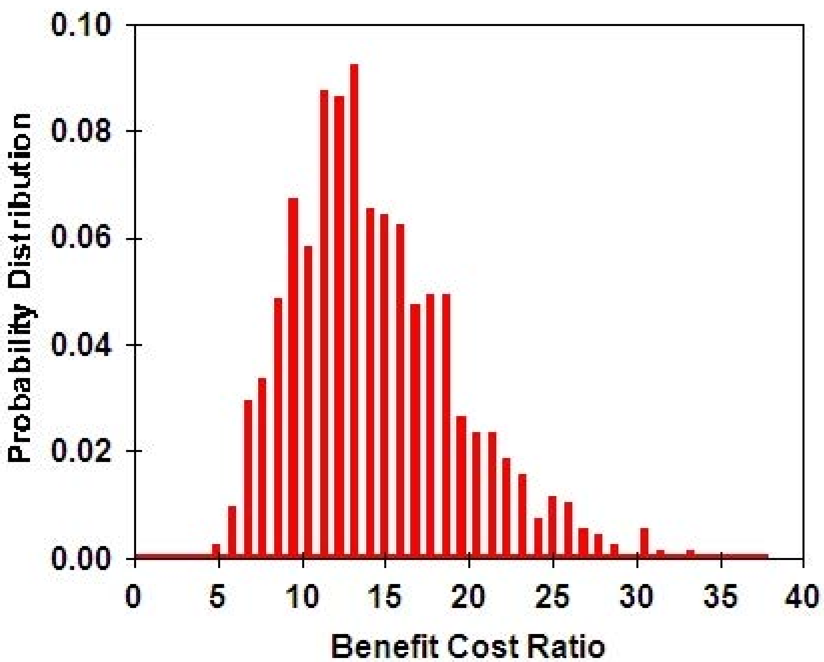
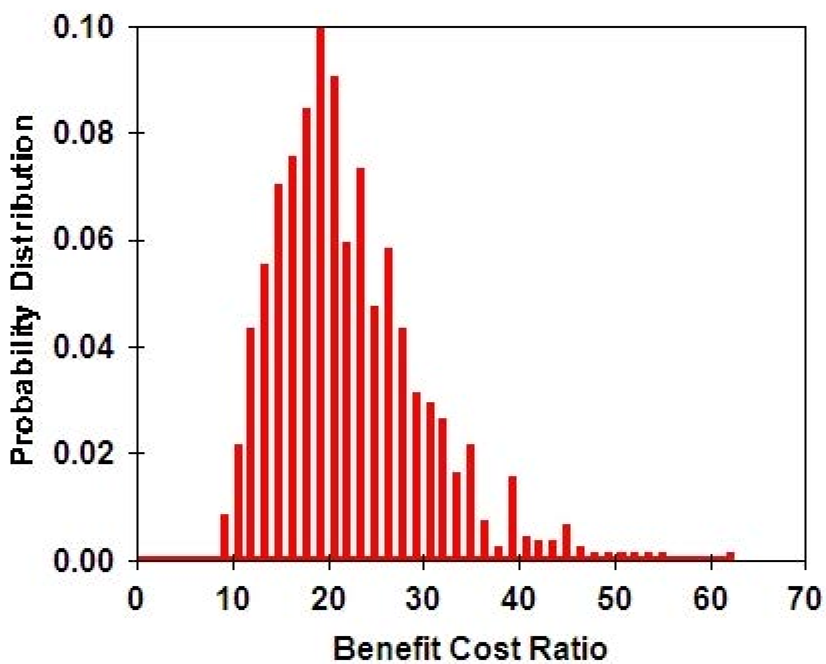


Fig 8: Histogram for B/C ratio for I-494 (AM Peak)

- Mean B/C Ratio = 14.79
- Median B/C Ratio = 13.95

- Cost-Benefit Analysis B/C Ratio = 13.42
- Confidence level that value will be greater than or equal to the Analysis Value = 60%

All



Corridors (AM Peak)

Fig 9: Histogram for B/C ratio for All Corridors(AM Peak)

- Mean B/C Ratio = 22.76
- Median B/C Ratio = 21.41
- Cost-Benefit Analysis B/C Ratio = 20.72
- Confidence level that value will be greater than or equal to the Analysis Value = 60%

I-35 W SB (PM Peak)

for I-

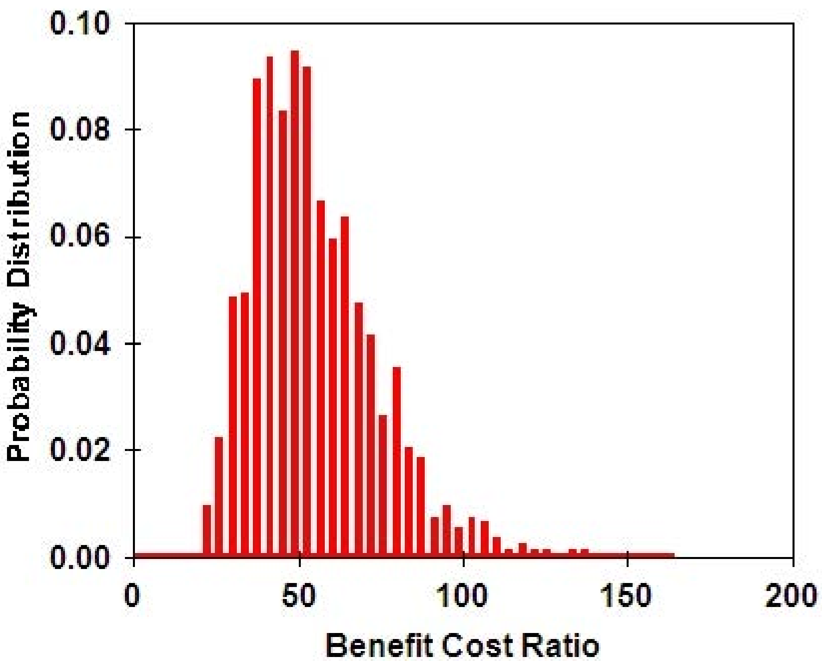


Fig 10: Histogram B/C ratio for 35 W SB (PM Peak)

- Mean B/C Ratio = 56.54
- Median B/C Ratio = 53.61
- Cost-Benefit Analysis B/C Ratio = 49.99
- Confidence level that value will be greater than or equal to the Analysis Value = 60%

I-35 E And I-694 (PM Peak)

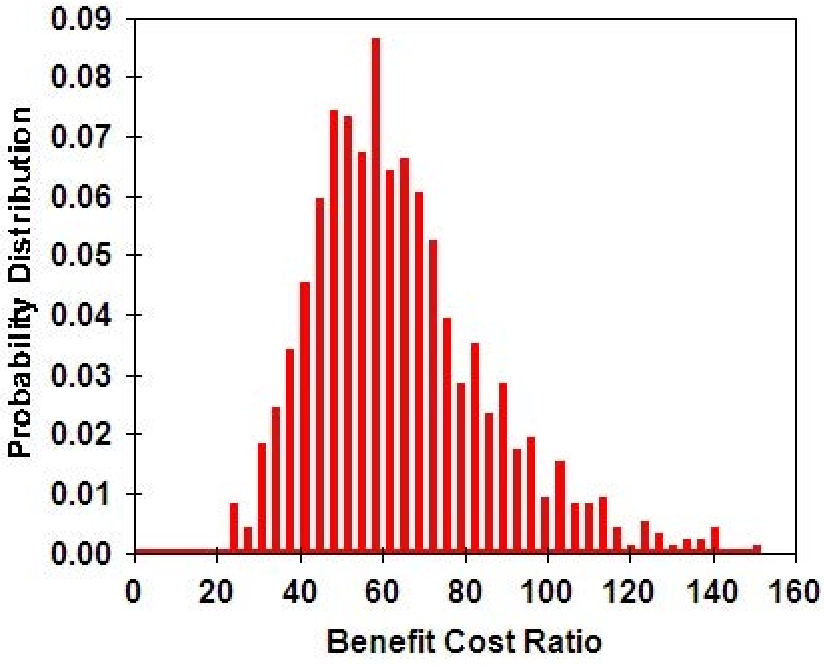


Fig 11: Histogram for B/C ratio for I-35E And I-694 (PM Peak)

- Mean B/C Ratio = 65.91
- Median B/C Ratio = 62.14
- Cost-Benefit Analysis B/C Ratio = 56.87

- Confidence level that value will be greater than or equal to the Analysis Value = 60%

TH-36 (PM Peak)

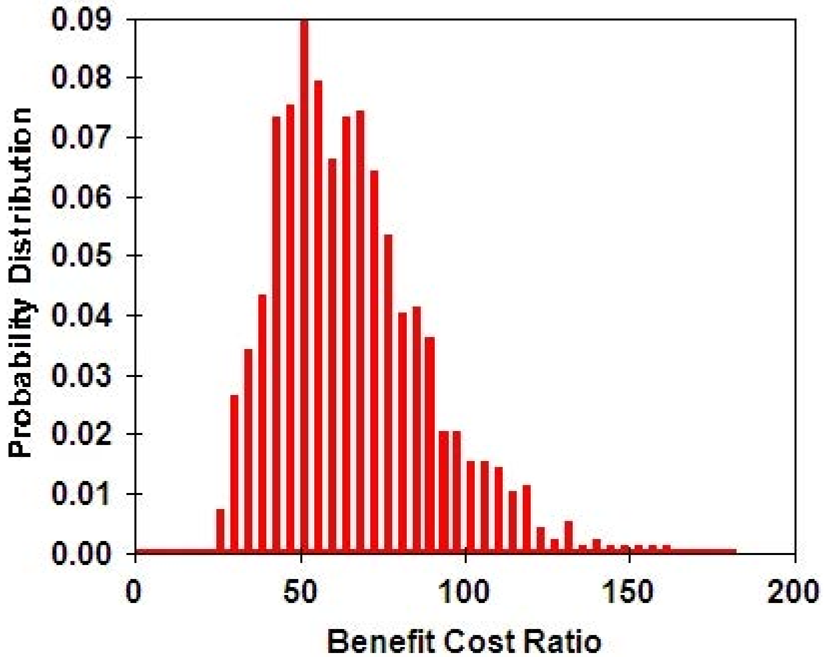


Fig 12: Histogram for B/C ratio for TH-36 (PM Peak)

- Mean B/C Ratio = 67.72
- Median B/C Ratio = 64.57
- Cost-Benefit Analysis B/C Ratio = 60.52
- Confidence level that value will be greater than or equal to the Analysis Value = 59%

I-94 And I-394 (PM Peak)

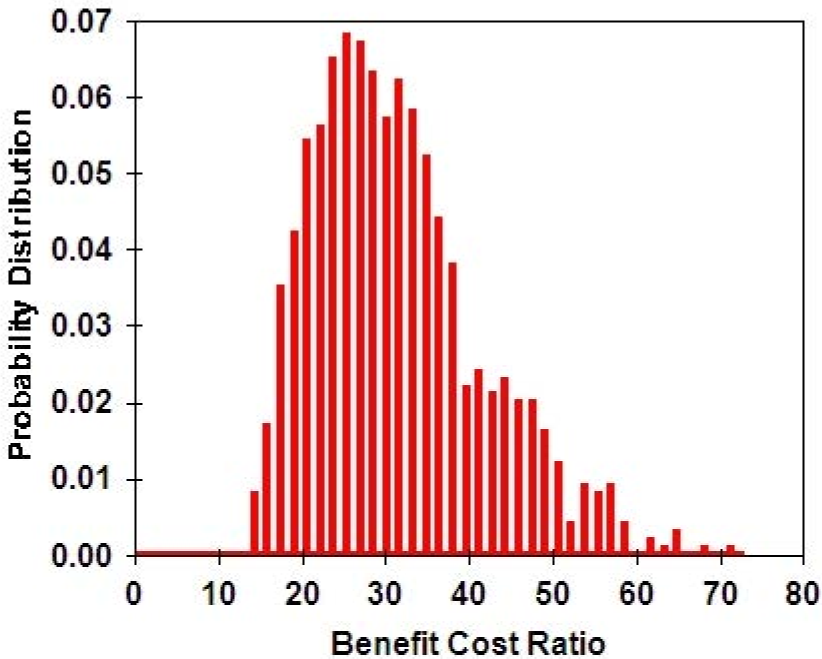


Fig 13: Histogram for B/C ratio for I-94 and I-394 (PM Peak)

- Mean B/C Ratio = 32.08
- Median B/C Ratio = 30.61
- Cost-Benefit Analysis B/C Ratio = 27.54
- Confidence level that value will be greater than or equal to the Analysis Value = 70%

TH-62 (PM Peak)

for

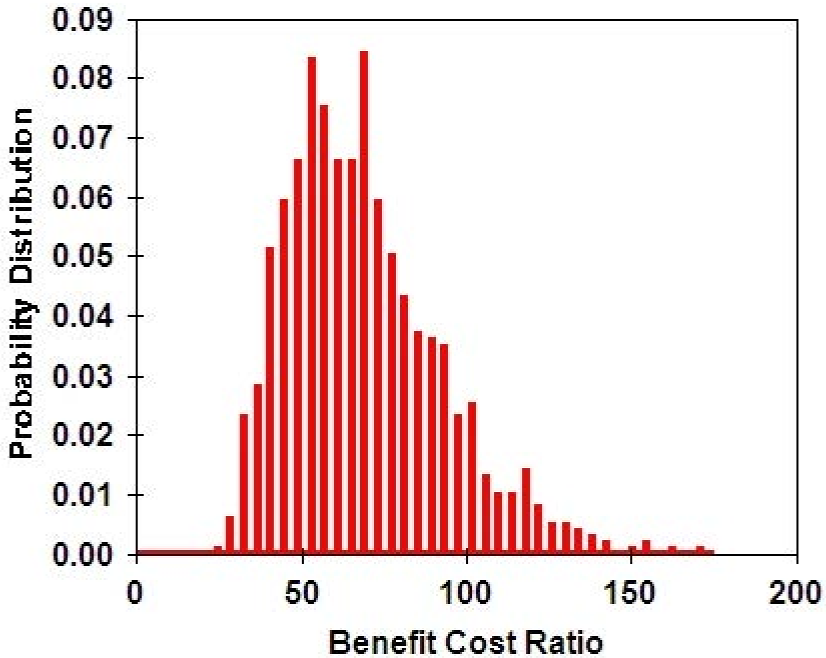


Fig 14: Histogram B/C ratio for TH-62 (PM Peak)

- Mean B/C Ratio = 70.77
- Median B/C Ratio = 66.99
- Cost-Benefit Analysis B/C Ratio = 62.12
- Confidence level that value will be greater than or equal to the Analysis Value = 57%

I-494 (PM Peak)

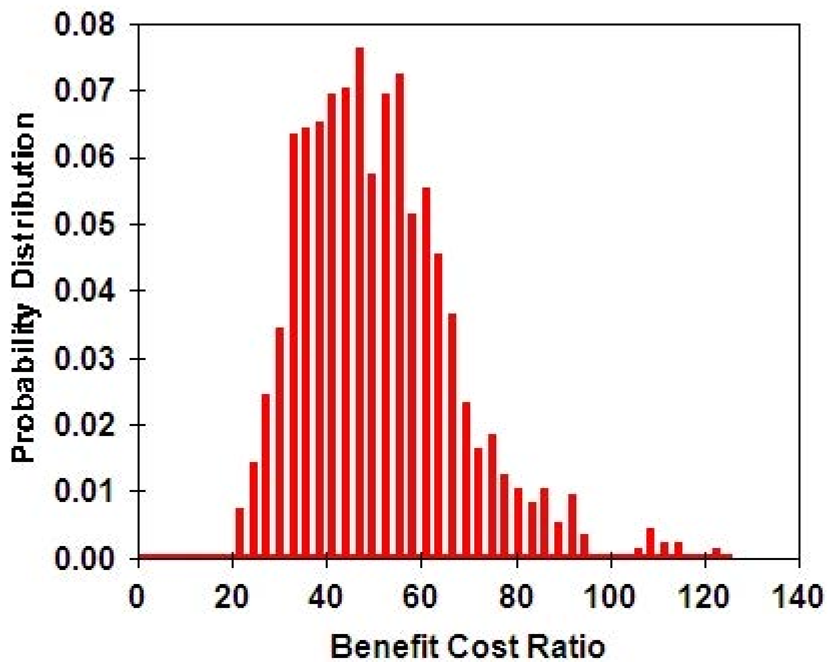


Fig 15: Histogram for B/C ratio for I-494 (PM Peak)

- Mean B/C Ratio = 52.23
- Median B/C Ratio = 50.25
- Cost-Benefit Analysis B/C Ratio = 45.12
- Confidence level that value will be greater than or equal to the Analysis Value = 70%

All Corridors (PM Peak)

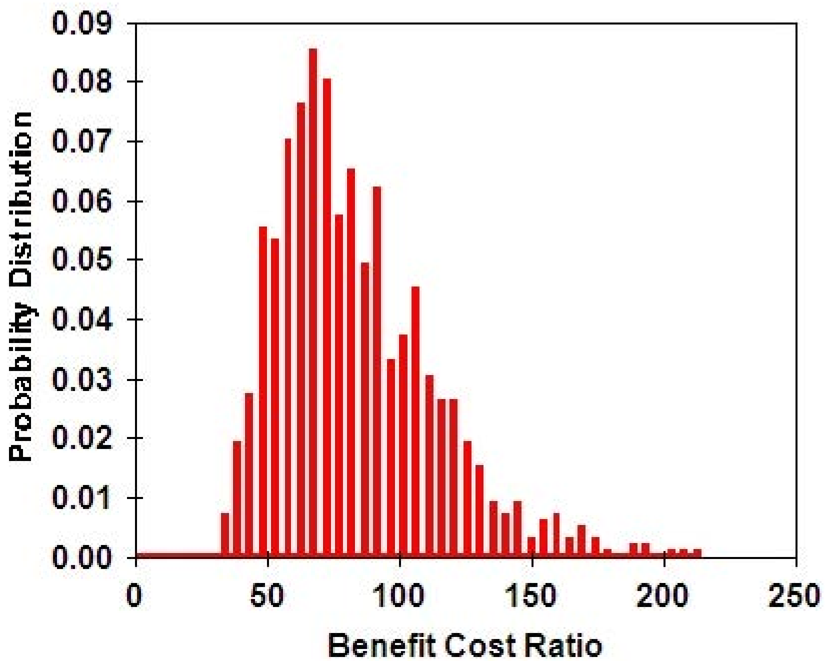


Fig 16: Histogram for B/C ratio for All Corridors (PM Peak)

- Mean B/C Ratio = 85.41
- Median B/C Ratio = 79.75
- Cost-Benefit Analysis B/C Ratio = 77.37
- Confidence level that value will be greater than or equal to the Analysis Value = 58%

APPENDIX F: STATE OF THE PRACTICE TECH MEMORANDUM

12/23/2009

Technical Memorandum #1: Literature Review & Contemporary Case Studies

Metropolitan Highway System Investment Study

Parsons Brinckerhoff

TECHNICAL MEMORANDUM #1: LITERATURE REVIEW & CONTEMPORARY CASE STUDIES

Metropolitan Highway System Investment Study

GLOSSARY

ARC: Atlanta Regional Commission 12
ATM: Active Traffic Management 2
BOS: Bus Only Shoulders 8
BRT: Bus Rapid Transit 2
Caltrans: California Department of Transportation 27
CMA: Congestion Management Agencies (California) 27
CRD: Congestion Reduction Demonstration 7
EIR: Environmental Impact Record 27
FDOT: Florida Department of Transportation 25
FHWA: Federal Highway Administration 3
FPI: Freeway Performance Initiative (San Francisco / Oakland) 27
FTA: Federal Transit Administration 2
GDOT: Georgia Department of Transportation 10
GPS: Global Positioning System 33
GRTA: Georgia Regional Transportation Authority 11
HCTRA: Harris County Toll Road Authority (Houston) 21
HOT: High Occupancy Toll 11
HOV: High Occupancy Vehicle 9
ITS: Intelligent Transportation Systems 2
LRT: Light Rail Transit 21
MPH: Miles Per Hour (speed) 9
MPO: Metropolitan Planning Organization 10
MTC: Metropolitan Transportation Commission (San Francisco / Oakland) 27
MTP: Metropolitan Transportation Plan 15
NCHRP: National Cooperative Highway Research Program 8
O&M: Operations and Maintenance 4
P&R: Park and Ride 23
PPP: Public Private Partnership 4
PSRC: Puget Sound Regional Council 33
ROW: Right of Way 23
RTC: Regional Transportation Commission (Dallas - Ft. Worth) 13
RTP: Regional Transportation Plan 19
SOV: Single Occupant Vehicle 36
TCRP: Transit Cooperative Research Program 8
TDM: Travel (Transportation) Demand Management 2
TIP: Transportation Improvement Program 20
TOD: Transit Oriented Design 23
TSM: Transportation System Management 2
TTI: Texas Transportation Institute 23
TxDOT: Texas Department of Transportation 21

1.0 Introduction

This memo documents the results of research undertaken to identify the different types of *Travel Demand Management* (TDM) and *Intelligent Transportation Systems* (ITS) that have been applied on limited access roadways in the U.S. and abroad These treatments are intended to reduce traffic congestion and improve traffic safety, through introduction of lower-cost improvements that could be developed within the existing roadway right-of-way, this avoiding the high right-of-way and construction costs associated with adding lanes on limited access highways to keep pace with traffic growth. This includes identifying successful treatments which have been applied in metropolitan areas with similar-sized limited access facilities to the Twin Cities area. These treatments in the past have been known as *Transportation System Management* (TSM) strategies.

Four basic strategies have been evaluated in this memo. *Active Traffic Management* (ATM) denotes application of advanced electronics to assign traffic priority, lane assignment and speed/queue control, and includes such systems as ramp metering, speed harmonization, queue warning, and dynamic re-routing. *Managed Lanes* include provision of dedicated lanes for use by high-occupancy vehicles, trucks, or any vehicle willing to pay a price to use lanes which operate at a higher speed than adjacent general purpose lanes. *Use of Shoulders* involves either operating buses on roadway shoulders in slower speed application to bypass general purpose lane traffic queuing during peak periods (as on the existing freeway system in the Twin Cities) or using the shoulders for general traffic during peak periods to maintain or provide added capacity, potentially in conjunction with the application of managed lanes on the inside of the roadway. Finally, *Bus Rapid Transit* (BRT) includes the provision of enhanced express bus services and introduction of limited-stop service with on-line stops.

Applicable strategies were assessed by conducting both an extensive literature review, and conducting "case studies" by making contact with agency representatives in seven urban areas in the U.S. on how they have applied different strategies, including the costs, funding, and impacts of system investments. The literature review included an overview of different FHWA documents addressing ATM and managed lanes, as well as documents reviewing applications in Europe. For BRT or bus on shoulder applications, relevant Federal Transit Administration (FTA) and Transit Cooperative Research Program (TCRP) documents were reviewed. The case studies were conducted for Atlanta, Dallas-Ft. Worth, Honolulu, Houston, Miami, San Francisco-Oakland, and Seattle. A template was used with a series of questions asking about the rationale for selection of certain treatments, how agencies are working together to implement such treatments, funding for capital and O&M costs, and the impacts of treatments and overall system investment on traffic congestion and safety.

2.0 Literature Review

A total of 75 documents were reviewed and are listed in the bibliography in Section 5.0. A summary of the content of some of the key documents reviewed follows:

Performance Evaluation Framework

FREEWAY PERFORMANCE INITIATIVE TRAFFIC ANALYSIS – PERFORMANCE AND ANALYSIS FRAMEWORK
Cambridge Systematics, October 2007.

This report presents a performance and analysis framework establishing traffic analysis goals and objectives for the San Francisco Bay Area Freeway Performance Initiative (FPI), and identifies corridor study analysis performance measures, analysis framework, expected output, and prioritization framework. The framework is intended to ensure that performance measures and analysis methods are consistent across corridors; are consistent across levels of analysis; are consistent across transportation modes, and address both recurrent and non-recurrent congestion.

The FPI objective is to develop a road map for selection of the best projects and operational strategies for the freeway system in the San Francisco Bay Area. The traffic analysis focuses on corridors, not on specific locations or projects. The analysis framework also addresses improved integration of parallel transit and arterials to enhance overall corridor performance. The regional-level prioritization process developed builds on individual corridor evaluations of projects and strategies that:

1. Provide a consistent assessment across corridors.
2. Normalizes various performance measures by specifying weights to corridor performance measures to account for varying detail of data for individual corridor evaluations, the desire to close HOV-lane gaps in a corridor, and the presence of heavy truck movements.
3. Provides a robust benefit-cost framework
4. Accounts for region wide priorities.

ACTIVE TRAFFIC MANAGEMENT

ACTIVE TRAFFIC MANAGEMENT: THE NEXT STEP IN CONGESTION
FHWA Office of International Programs, July 2007.

This report summarizes a 2006 scanning tour of a FHWA-sponsored delegation to Greece (Athens), Denmark (Copenhagen), England (London, Birmingham), Germany (Bergisch-Gladbach, Cologne, Frankfurt) and the Netherlands (Rotterdam, Utrecht) to meet with transportation agencies on how Europe is addressing active traffic management in operating their major highway facilities in urban areas. The group included Chuck Fuhs, a member of the MHSIS consultant team.

In Europe, the primary active traffic management strategies that have been applied for managing recurrent congestion are speed harmonization and temporary shoulder use. These treatments are also used for addressing non-recurrent congestion, as well as dynamic rerouting.

The speed harmonization systems are configured primarily to automate deployment based on certain travel speed and traffic volume thresholds. In the Netherlands, these systems have reduced collisions by about 16%, and have increased throughput from 3 to 5%. Lane control and speed limit signs in general are spaced about every 1/3 mile.

Temporary shoulder use in Europe is typically deployed with speed harmonization, and has been applied starting in the 1990s in Germany. While typical shoulder use relates to right-hand shoulders, in the Netherlands and Germany, some application of left-hand shoulder use under certain congestion conditions is allowed.

Dynamic rerouting is used in several European countries to provide alternate route information of roadway users during incidents. The dynamic message and guide signs in Germany are adaptable to provide information when even temporary shoulder use is in effect. The spacing of freeway detectors is typically 1/3 to 2/3 mile, and such dense application of detection along with CCTV cameras provides a detailed data backbone from which dynamic rerouting and other active traffic management strategies can b implemented.

Several of the European countries visited also have queue warning systems integrated with their active traffic management systems. Signage for such systems has varied from use of a pictograph in Germany to flashing lights on the variable speed limit signs in the Netherlands.

All of the European countries visited, like the situation in the U.S., recognize that there are insufficient funds to undertake major capacity improvement projects on major urban highways, and thus TSM strategies have become the focus. The use of Public Private Partnerships in Europe to implement TSM strategies has been increasingly popular, with its most extensive application to date in England. The majority of benefits on transportation PPPs have been realized in O&M cost savings over the life of a contract (up to 70% over 30 years). Achieving performance thresholds are a cornerstone to a successful PPP, and contracts in Europe have included measures related to improved operations, reduced delay, and fewer incidents. In most cases, concessionaires have combined private fund with some level of public finances to fund projects.

An Approach to Assessing Freeway Lane Management Hot Spots

Transportation Research Record Vol. 2099, 2009.

This research presents a procedure for capitalizing on the trade-off between urban freeway managed lanes and general purpose lanes that compete for limited road space. The basic goal of the procedure is to provide policy guidance for sharing any excess lane capacity on a timely and efficient basis. Potential operating policy options for these two types of lanes are categorized as "do nothing," "lane management," and "more than lane management." The "lane management" condition recognizes the extent and duration of a "hot spot" as defined by underutilized managed lanes with congested general purpose lanes, or vice versa. Four major and three minor lane management hot spots are deterministically and stochastically captured along a 24-mi freeway stretch in California. The major hot spots account for 8.3% of the total time-space set. The approach, which can also be applied to predict upcoming hot spots, generates satisfying accuracy. Finally, strategies are proposed to prevent the hot spots, and the effects of lane management are estimated. The application of this approach is useful especially for managed lanes with limited access points that prohibit arbitrary lane changing

INVESTIGATION OF SOLUTIONS TO RECURRING CONGESTION ON FREEWAYS
Virginia Department of Transportation, 2009.

The highway operational strategies implemented to reduce recurring congestion have shown promising results abroad where there is an extensive use of ATM systems. To prove the effectiveness of a better managed freeway in mitigating recurring congestion, this study tested the effectiveness of an active traffic management system on a simulated model of I-66 and I-95 in Northern Virginia. Hard shoulders, variable speed limits, and ramp metering are several active traffic management systems simulated in this study. The simulation model was based on the geometric characteristics, ramp volumes, vehicle flows, and speeds of actual recorded conditions. Compared with the simulated control conditions, the results of the study indicated improvements in average fuel economy, travel delay, delay of the onset of congestion, and reduction of queues. The two ATM systems, i.e., variable speed limits and hard shoulders, showed the highest potential for reducing recurring congestion and should be considered as potential countermeasures in congested corridors.

ROAD WEATHER INFORMATION SYSTEMS, WISCONSIN ROAD WEATHER SAFETY AUDIT PLAN AND IMPLEMENTATION
University of Wisconsin, 2009.

Specific to Minnesota congestion and safety problems are weather considerations. This series of reports conducted by the University of Wisconsin Traffic Operations and Safety Plan is a comprehensive look at countermeasures which can improve roadway function in adverse weather conditions. Of special note are the literature review and countermeasure documents, which are included as appendices to this report.

MANAGED LANES

MANAGED LANES HANDBOOK
Texas Transportation Institute, October 2005.

This report, prepared for the Texas Department of Transportation, presents detailed information on planning, funding, designing, and implementing managed lane facilities.

The handbook includes a basic discussion on the definition and classification of different types of managed lanes. Also addressed are public outreach strategies, managed lanes weaving, ramp and design issues, driver information needs and associated traffic control devices for managed lanes, enforcement and incident management strategies, monitoring and evaluating managed lanes facility performance, interim use during construction, special events and emergencies, and staffing and training related to managed lanes development and operations coordination.

The handbook offers guidance based on a number of active managed lanes facilities implementations, along with use of micro-simulation modeling to evaluate more complex operating scenarios, particularly entrance and exit maneuvers to and from managed lanes facilities.

A strategy selection tool is presented to provide a preliminary screening methodology that would help define the types of managed lanes strategies that would be applicable in a particular corridor. Included with this tool is an association of typical project objectives related to different goals and managed lanes strategies. In addition, once planners have selected objectives that are deemed important, a list of 20 general constraints (related to physical conditions, truck characteristics, origin-destination patterns, land use, price elasticity and willingness to pay, and funding) have been identified that must be evaluated before a particular managed lane strategy can be identified.

The design section of the handbook presents basic design values related to alignment and operational conditions, representative cross sections, and design considerations for terminal and access treatments. Design configurations for both concurrent-flow and reversible-flow managed lane facilities are provided, including tradeoffs involving lane, shoulder, and buffer width. Guidelines for selecting particular ramp types for managed lanes special access facilities (T-ramp with or without park-n-ride, flyover ramp, at-grade slip ramp with freeway) are also provided.

The handbook also addresses what information needs drivers will have associated with use of managed lanes facilities, translated into traffic signing and pavement marking treatments. The information categories evaluated include: entrance information, exit information, hours of service, incident management information, occupancy requirements, open/closed information, time savings, tolling information, travel time, type of managed lanes, and vehicle restrictions. Information needs related to familiar drivers, semi-familiar drivers, and unfamiliar drivers are provided. The tradeoffs between use of static vs. variable message signing to convey different messages are also addressed.

The handbook also identifies various enforcement strategies which can and should be undertaken to preserve free-flow operations on managed lanes facilities, ranging from continuous enforcement (using automated technology) to the simpler process of self-enforcement. Specific design guidelines related to the placement and layout of enforcement areas under low and high-speed conditions are identified.

There is a recognition in the handbook that managed lanes cause some unique challenges related to incident management. This includes incident responder access to a crash scene, impact of adjacent roadway incidents to managed lane operations, pre-positioned response crews, and mutual assistance agreements between managed lane agencies and general purpose lane agencies where different.

EVALUATION PLAN FRAMEWORK FOR 95 EXPRESS MANAGED LANES
Cambridge Systematics, 2009 and

95 EXPRESS MIDYEAR REPORT
Florida Department of Transportation District 6, October 30, 2009

The evaluation framework report identifies a set of goals and objectives, performance measures, data needs, analysis methodologies, and locations for data collection and analysis segments for use in assessing the impact of the new 95 Express managed lanes on I-95 in Miami. Four major project objectives were derived around which performance measures were developed:

1. *Measure project impacts on corridor performance* (travel volume, travel speeds, travel time, level of service, peak-period distribution, vehicle classification, vehicle occupancy, vehicle and person throughput, mode split, emissions/noise, fuel consumption, travel behavior)
2. *Measure project utilization* (toll usage, transit ridership, park-n-ride utilization, HOV registrations, hybrid registrations, telecommuting)
3. *Assess project operations and effectiveness (operational efficiency)* (toll revenue, operations and maintenance costs, levels of enforcement, incident frequency and duration, crash frequency and severity, equipment malfunctions/availability)
4. *Measure project acceptance and satisfaction* (user and non-user acceptance and satisfaction, public perception, signage effectiveness, business impacts, media coverage, equity)

These performance measures are consistent with those identified in the October 2008 Urban Partnership Agreement (UPA) and Congestion Reduction Demonstration (CRD): National Evaluation Framework.

A specific set of data needs were identified associated with the different performance measures. Data was stratified into quantifiable traffic, transit and environmental data, and public perceptions. A survey of both users and non-users was conducted to collect mode split, trip making changes, signage effectiveness, business impacts, project perception, acceptance, and satisfaction, and socio-economic data to estimate equity impacts. A separate employer survey was also conducted.

The 95 Express evaluation report presents data and analysis that showed that the initial managed lanes implementation on northbound I-95 through north Miami has been a success. The reporting period is from the first day of tolling in December 2008 through June 30, 2009. Important statistics to note:

- Customers using managed lanes have almost tripled their average travel speed during PM peak periods, from 20 mph to 57 mph.
- Drivers staying in the general purpose lanes have also experienced a significant increase in average travel speed, from 20 mph to 41 mph.
- Average volume along the managed lanes in the PM peak period (4 to 7 PM) was nearly 7,000 vehicles, or 28% of all northbound I-95 traffic. Vehicles traveled at speeds I the managed lanes over 45 mph 95% of the time.
- The managed lanes have remained open to motorists 95.5% of the time.
- The number of vehicle trips served by the managed lanes (4.2 million) was 130% higher than originally projected, with over 46,000registered toll exempt trips by over 7,000 registered vehicles.
- Actual total revenue ($2.8 million) with 89% of projected.
- Charged tolls ranged from $0.25 to $5.00. The average monthly maximum toll charged was $3.64. About 85% of the managed lane customers were charged $1.61 or less.
- 95 Express bus ridership increased by about 30% between the first three months of 2008 vs. the first three months of 2009.

- Operating and maintenance costs for the facility were about $3.25 million over the reporting period.
- Public surveys have shown that 76% of those using the 95 Express lanes feel it is a more reliable trip than if in the general purpose lanes, and 58% of commuters familiar with the express lanes would like to see them developed elsewhere in south Florida.

USE OF SHOULDERS

NCHRP REPORT 369: USE OF SHOULDERS AND NARROW LANES TO INCREASE FREEWAY CAPACITY

JHK Associates, 1995.

This research project developed a methodology to evaluate the feasibility and impact of narrowing travel lanes and using shoulders to increase freeway capacity, and included design guidelines for implementing road improvement projects with these elements. The factors that impact their effectiveness include traffic volume, vehicle mix, capacity, horizontal and vertical alignment, length of application, ability to provide vehicle turnouts, and incident response issues. Eleven limited-access highway corridors around the U.S. (in Atlanta, Boston, Los Angeles, Minneapolis, Northern Virginia, and Seattle), were evaluated with respect to how traffic level of service and accidents changed with respect to implementing narrow lanes and/or use of shoulders.

The research found that when an added lane is developed through just using the shoulder or narrower lanes over an extended distance, the safety performance of the corridor can be negatively impacted. However, more limited applications of these strategies in a corridor – to address lane balance, lane continuity and bottlenecks – have been more successful, with no significant change in accident experience, Also a difference in lane width (from 12 to 11 feet) alone has not had a significant safety impact.

Based on the research findings, it was recommended that narrow lane/use of shoulder strategies be reserved for use only in congested highway corridors, and be for congestion relief, and not applied in general over an extended length. Restriction in travel lane width to 11 feet should be a first modification considered. Reduction of the left shoulder should be considered before reducing the right shoulder.

TCRP SYNTHESIS 64: BUS USE OF SHOULDERS

Wilbur Smith & Associates, 2006.

This research involved a survey of existing applications of bus use of shoulders (BOS) on freeways and arterials in North America. The synthesis involved review of existing bus operational conditions associated with shoulder use, impact on general traffic operations, and use of ITS to designate and monitor shoulder use by buses. Case studies were undertaken for six urban areas with such treatments (Minneapolis-St. Paul; Northern Virginia, Miami, San Diego, Toronto, and Dublin, Ireland), with another eight urban areas (Atlanta, Bethesda, MD; Northern New Jersey; Ottawa, ON; Vancouver, BC; Wilmington, DE; Auckland, NZ) responding to the initial survey.

The minimum desired shoulder width to accommodate bus operations was found to be 10 feet. The extensive application of BOS treatments on the Twin Cities freeway system has resulted in other urban areas following suit to allow operation o buses on shoulders under low speed freeway conditions (25 to 35 MPH), or not faster than (10-15 MPH) than the adjacent general freeway traffic. Actual data on operations and patronage benefits was limited at the time of this research, recognizing that newer projects, particularly those involving FTA funding, would need to provide more rigorous analysis of feasibility and impact for future applications.

To date, most BOS operations have involved using conventional signage to warn both motorists and bus drivers on the use of the shoulders by buses and assignment of right-of-way at interchange on and off-ramps. There is emerging application of ITS technology for BOS operations. In particular, on I-66 in Northern Virginia, overhead message signs advise motorists as to when shoulder lanes are open to general traffic, which could be applied to BOS operations. There is also continuing research on the application of driver assist technology, including lane keeping assistance systems.

Bus Rapid Transit

TCRP Report 90, Planning and Design Guidelines for Bus Rapid Transit
Transit Cooperative Research Program, 2005, and *TCRP Report 118, BRT Practitioner's Guide*, 2007.

These two research reports review the characteristics of bus rapid transit systems, including the costs and impacts of different bus rapid transit components, and how to package different BRT components to provide an overall BRT operation in a corridor that meets estimated ridership demand and physical, operational, community, and funding constraints. Included is a review of the application of express bus and limited stop BRT service, on limited access facilities. Different BRT operating configurations on freeways including High Occupancy Vehicle (HOV) and separate busway applications are reviewed. This includes different roadway cross sections and ingress and egress treatments for bus-only facilities. In TCRP Report 118, a new "bottoms-up" ridership estimation to estimate BRT ridership demand off existing conditions in corridors is presented, including diversion from existing transit, auto drivers diverting transit, and new "induced" transit trips.

Characteristics of Bus Rapid Transit, 2nd Edition
National Bus Rapid Transit Institute, 2009.

This report presents a summary of the characteristics of bus rapid transit, including a comprehensive survey of different running-way and service configurations, including operation on limited-access roadways. The key feature of this document is extensive survey data from numerous cities in the U.S., Canada and around the world related to BRT facility running ways, station treatments, vehicle design, ITS components, and service design.

3.0 Case Studies

Metropolitan Planning Organization (MPO) and transit agency staff from seven urban areas around the U.S. (Atlanta, Dallas-Ft. Worth, Honolulu, Houston, Miami-South Florida, San Francisco-Oakland

Bay Area, and Seattle) were contacted to obtain information on how they are addressing future investments in their major highway systems, including corridor identification, application of new technology, performance measures, and funding for implementation. A template was prepared to guide the PB team in obtaining and documenting information receives. This case study documentation is presented on the following pages.

Atlanta

Overview

Agencies: Atlanta Regional Commission, Georgia Department of Transportation (GDOT), Georgia Regional Transportation Authority (GRTA), State Road & Tollway Authority (SRTA), Metropolitan Atlanta Rapid Transit Authority

Years of Experience with Managed Lanes / Active Traffic Management: 2002 - current

Brief History:

- 2009 – Metro Atlanta Managed Lanes System Plan completed
- 2008 –$110 million grant awarded to GDOT to support $147 million pilot project through USDOT Congestion Reduction Demonstration Program. Relates to I-85 HOT lanes project (I-285 to Old Peachtree Road), to be operational by 2011.
- 2007 – Adoption by ARC of Managed Lane Policies for Atlanta Region
- 2005 – Creation of Managed Lane Planning Team by ARC
- 2002 – GDOT adopts first Regional HOV System Plan.

Population: 4,440,000 (2007)

Congestion: 75% of peak VMT congested, 58% of lane miles congested, 57 annual person hours of delay per peak traveler (2007)

Management Program Description

The Region

From 1982 to 2007, population in the Atlanta urbanized area doubled, from 2.25 million to about 5 million. The size of the urban area also almost doubled over this 25-year period, from 1,700 to 3,050 miles. Given these trends of population to urban area size, the population density within the region only slightly increased from 1982 to 2007. However, traffic growth, tripled in this 25-year period, going from 30 million vehicle miles per weekday in 1982 to over 90 million in 2007.

Management Strategies Deployed / Studied

The Atlanta region has been very active over the past ten years in the development of TSM strategies to provide a more efficient regional highway system. Since 2002, there has been a focus on the development and implementation of a HOV System Plan, which in recent years has been focused on the development of managed lane development strategies. This has culminated this year in the adoption of a Managed Lanes System Plan for the Atlanta region.

A five-tiered implementation program has been identified for the Metro Atlanta Managed Lanes system, totaling $16.2 billion (with $7 billion estimated funding gap, assuming PPP delivery). The projects to be included in the different tiers based on five criteria:

1) Traffic Congestion
2) Connectivity
3) Ease of Implementation
4) Design and Environmental Activities Underway
5) Level of Public Financial Contribution

A specific set of 12 managed lane corridors for the Atlanta region were derived from GDOT's 2002 HOV System Plan, with 25 evaluation criteria applied. Once the managed lane corridors were identified, specific lane operation, number of lanes, and facility location options were evaluated. Lane operations considered included both reversible lanes and bi-directional lanes. The use of one vs. two lanes in each direction was also assessed. Facility location options considered included elevated, at-grade, inside median and outside median. The assessment also identified locations where direct ramp connections between managed lane corridors should be developed.

I-85 High Occupancy Toll (HOT) Lanes is the first project in the Managed Lanes Plan to be implemented. Project will convert about 15 miles of existing HOV lanes to HOT lanes from I-285 in DeKalb county to Old Peachtree Road in Gwinnett County. The transit component will be provided by GRTA, with 36 new commuter coach buses to serve seven routes in the corridor. GRTA also will construct two new park-n-ride lots, totaling 1,900 new parking spaces. Transit will use the HOT lane toll-free.

Selection Criteria

In the development of the Metro Atlanta Managed Lanes System Plan, GDOT applied 25 evaluation criteria to screen the corridors identified in GDOT's 2002 HOV System Plan to identify an initial Managed Lanes network. These criteria include:

- Functional Classification
- Presence of Existing Managed Lanes
- Trip Lengths: >10 miles
- % of Vehicles with 2+ Occupants
- Total Vehicles
- Total Trucks
- Total HOVs
- Volume to Capacity (V/C) Ratio
- Duration of Congestion (# of hours)
- Travel Time Index
- Percent of Persons Residing Within 5 Miles (2005)
- Percent of Persons Residing Within 5 miles (2030)
- Percent of Jobs Located Within 5 miles (2005)
- Percent of Jobs Located Within 5 miles (2030)

- Environmental Justice Populations Located along Corridor
- Interchanges per Mile
- Number of System Connections
- Number of Freight Connections
- Presence of Existing Express Bus
- Presence of Planned Express Bus, BRT
- Presence of Existing Park-n-Ride Lots
- Presence of Planned Park-n-Ride Lots
- Candidate for Truck Only Lanes
- Design Activity Already Underway
- PPI Proposed Along Corridor

Responding to Strategic Planning Challenges

Long Range Transportation Plan

As an input to the 2030 Environ6 Regional Transportation Plan for the Atlanta Region, the ARC Board in 2007 adopted a set of Managed Lane Policies to guide the identification of management and operations strategies on the regional expressway system and provide a framework for a Regional Managed Lanes System Plan. Policies were identified for five key areas: 1) Efficiency 2) Revenue 3) Regional Goals 4) Transit and 5) Accessibility. Congestion management was identified as the primary objective in designing future managed lane systems.

Multimodal Corridors

In the development of the Metro Atlanta Managed Lanes system Plan, three key decisions were made with respect to the use of lanes and designed design and operating characteristics. It was assumed that ideally two managed lanes would be provided in each direction, as warranted:

- Decision #1 – Occupancy: HOT 3+ operation
- Decision #2 – Maximum revenue or maximum efficiency: Managed lanes "value priced" to maintain a minimum 45 mph travel speed
- Decision #3 – Who is allowed to access lanes? Accommodate cars, transit, and light-duty trucks
- Decision #4 – Convert Existing GP Lane to a Managed Lane? Only on most constrained corridors/option of last resort.

Dallas – Fort Worth Area

Overview

Agencies: North Central Texas Council of Governments / Regional Transportation Commission (MPO), Texas Department of Transportation (TxDOT), Dallas Area Rapid Transit (DART), North Texas Turnpike Authority (NTTA)

Years of Experience with Managed Lanes / Active Traffic Management: 1991 - current

Brief History:

- 1991: Opened first HOV lane on I-30 in 1991, a contra-flow HOV facility with moveable barrier.
- 1996 – 1997: Opened various-type (concurrent flow, reversible flow) HOV lanes on I-35E and I-635
- 2000 - 2002: Opened concurrent flow HOV lanes on US 67 and I-35E
- 2000 - 2004: Conducted EIS recommending construction of priced managed lanes on I-635
- 2005 – current: Construction activities commence on I-635 priced managed lanes
- 2005 – 2008: Completed construction of I-30 Managed HOV Lanes facility; tolling anticipated on the lanes starting in 2010.

Population: 4,445,000 (2007)

Congestion: 66% of peak VMT congested, 43% of lane miles congested, 53 annual person hours of delay per peak traveler (2007)

Management Program Description

Management Strategies Deployed / Studied

The North Central Texas (Dallas – Fort Worth) region has operated under a non-traditional planning regimen for over a decade. In 1993, the regional transportation commission (RTC) adopted a policy which stipulated that any new highway capacity using federal aid funds must first be reviewed for toll road viability. As a result of this policy, all long range transportation plans adopted by the MPO have been examined for viability. The region has evolved the policy to not only include traditional concepts of toll roads, but also toll lanes and managed lanes.

An additional limitation has been Dallas – Fort Worth's non-attainment status, which has affected the region's deployment of managed lanes. Whereas initial construction of HOV lanes occurred to satisfy air quality requirements, changes over time have led the region to conclude it will soon no longer remain constrained due to emissions improvements. In time, the region anticipates a change from HOV lanes to managed lanes where HOV users are provided benefits only in the off-peak periods.

Managed lanes are currently treated the same as HOV lanes in selection process from an air quality perspective. However, the RTC created a regional managed lanes / value pricing policy in 2007 that identified 1) managed lanes as the preferred capacity expansion process for the Dallas – Fort Worth region, and, 2) HOV discounts would not be assumed into the future. The next iteration of the long range plan will provide a process for adapting existing HOV lanes to managed lanes, and, altering capacity expansion plans to a managed lanes pursuit.

FIGURE 1: HISTORY OF REGIONAL MANAGED LANE POLICIES, NCTCOG, 2009.

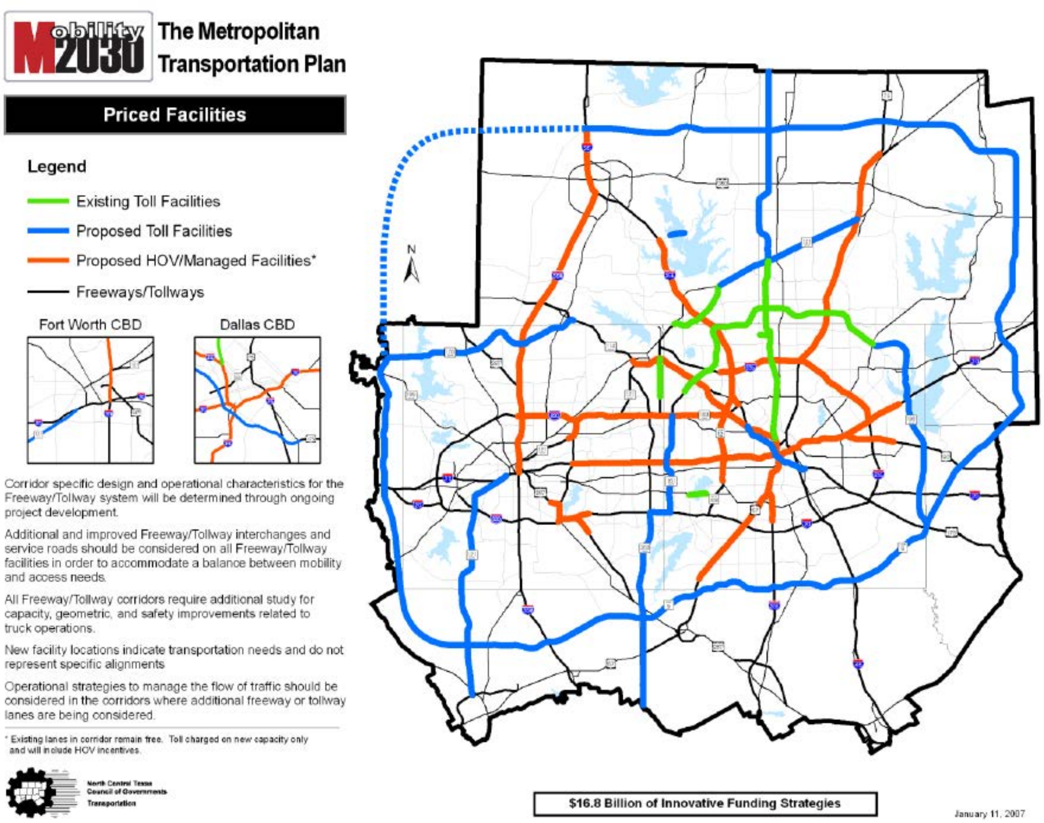


FIGURE 2: PLANNED REGIONAL MANAGED LANES / FACILITIES, NCTCOG, 2007.

The regional managed lane policy provides a phasing for tolls on the facilities. The policies are summarized:

- Fixed-fee toll schedule will be used for the first six months of operation; dynamic pricing thereafter in order to "smooth" curves prior to adoption of dynamic pricing
    - The fixed-fee schedule will be adopted per-mile, up to $.75/mi.
    - Rates will be updated monthly
- Transit vehicles will not be charged a toll
- SOV's will pay the full rate, with trucks paying a higher rate
- HOV-2+ will pay the full rate in the off-peak period; 50% discount during the peak periods
    - As the air quality attainment maintenance period is phased out, the discount will be discontinued

Selection Criteria

The most recent long range transportation plan emerged from a large gap between available funding and needed transportation projects. In order to do more with less funding, the region adopted a screening process which first allocated revenues to low cost / highly cost effective, and/or, most air quality beneficial projects and programs. This included congestion management, transit, and HOV systems. More traditional capital intensive projects where then included only if they could be afforded (including an examination of toll viability) and did not exacerbate the air quality of the region.

Responding to Strategic Planning Challenges

Long Range Transportation Plan

The Dallas – Fort Worth Metropolitan Transportation Plan (MTP), the long-range transportation plan for the region, incorporates an emphasis upon preservation of the existing transportation system. Regionally, over $21 billion in the plan has been designated towards system operations, maintenance, rehabilitation, and safety. Of this, more than $2 billion is dedicated towards congestion management and operations, including system and demand management. Managed lanes are not considered a part of congestion management strategies; rather, they constitute their own category of capacity projects.

As mentioned above, the MTP adopted a process for selecting projects for the long range plan. The prioritization is as follows:

1) Enhance efficiency of the existing system, through the elimination of trips through demand management and more productive use of highways through system management
2) For those trips that cannot be eliminated, encourage a mode shift to bus and rail
3) Increase auto occupancy for those trips that cannot be persuaded to use transit, through the development of HOV and managed lanes
4) Single-occupant vehicle capacity considered only for those congested corridors where previous efforts as outlined above have not been successful.

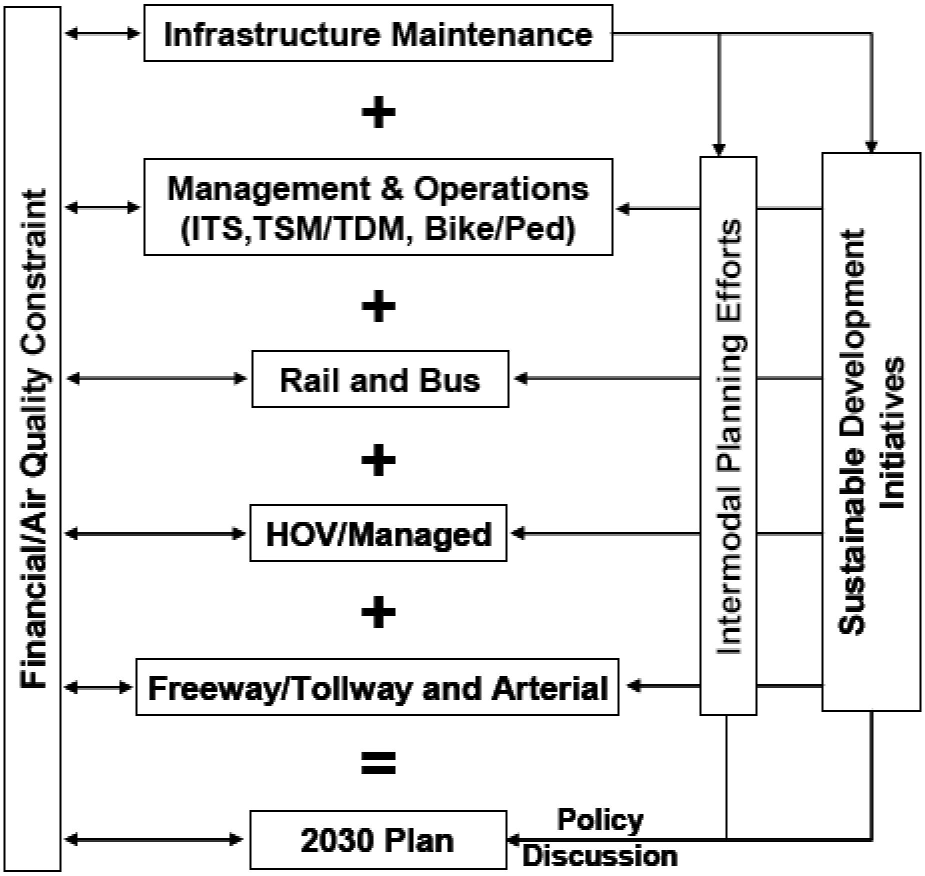


FIGURE 3: PLANNING PROCESS FOR DALLAS-FT. WORTH REGION, MOBILITY 2030, NORTH CENTRAL TEXAS COG, 2009.

Funding Issues

Funding limitations have forced the change in both capacity preference and HOV policy to managed lanes. The region cannot afford the revenue leakage that comes with preferential treatment of HOV's in their managed lanes. In addition, the region has pursued an "aggressive" financial plan (as stated in the MTP). This plan provides overly optimistic scenarios for funding, so that if funding does arrive, how it is spent is addressed directly in the plan. These assumptions state that 25% of managed lanes costs will be covered by toll revenue, and, 100% of toll roads will be covered by toll revenue.

Interchanges

Interchanges are only prioritized for freeway-to-freeway connections. All other interchanges are subject to case-by-case analysis.

Performance Measures

The principal performance objectives from the region's development of toll and managed lane facilities are to:

- Provide additional capacity in congested corridors
- Provide trip reliability for HOV and transit
- Improve air quality and increase vehicle occupancy, and enhance person movement
- Generate revenue to construct facility
- Generate revenue to operate and maintain facility
- Increase corridor efficiency
- Provide for operational flexibility in response to changing corridor needs

Multimodal Corridors

The region's long range plan adopts an established hierarchy in uses of funds, and, preference for multimodal transportation. Bus and rail transit are preferred directly in plan expenditures to HOV travelers, who are in turn preferred to SOV users. This hierarchy illustrates the delineation of managed lane corridors from rail corridors, for example.

Honolulu (Oahu)

Overview

Agencies: Oahu Metropolitan Planning Organization

Years of Experience with Managed Lanes / Active Traffic Management:

- Managed Lanes: HOV (time of day based, 2+), zipper lane (contra-flow AM peak only – planning underway for an afternoon option at some point), shoulder use (peak period, but thinks that people use them during off-peak as well – enforcement is difficult and lane looks like a standard lane all the time, shoulder mount static sign only).
- Traffic Management/ITS: Traffic Management Center (City & County of Honolulu and Hawaii DOT), VMS (about 12 or so, all on interstate system), no ramp metering, there is a long-term plan/desire to merge the State's and City & County's TMC's and integrate it with the State's and City & County's Department of Civil Defense and Department of Emergency Management, respectively.

Population: 705,000 (2007)

Congestion: 57% of peak VMT congested, 51% of lane miles congested, 26 annual person hours of delay per peak traveler (2007)

Management Program Description

Management Strategies Deployed / Studied

The Honolulu area has a rich history with deploying operational and management strategies

- HOV lanes on H-1 between the Waiawa and Keehi interchanges, on Moanalua Freeway from Halawa to Puuloa Road, and on Kalanianaole Highway from West Halemaumau Street to H-1, and on H-2 from the Mililani interchange to the Waiawa interchange.
- Reversible (Zipper) Lanes (contra-flow) on the H-1 freeway and two primary arterials during peak periods.
- Tolling is being evaluated for the Regional Transportation Plan as a scenario (making the afternoon zipper lane a toll facility with variable pricing). There is debate in the Legislature regarding tolling authority. City and County of Honolulu does have the ability to institute cordon pricing, and the Oahu MPO will be looking at cordon pricing as a scenario in the 2035 Plan (it is a preliminary look to see if it is something they should study in more detail).

In addition, the region is exploring highway modernization activities including expansion/standard upgrades, shoulder lanes, and active management strategies.

Selection Criteria

Thus far, there has been no single approach to screening or selection of management and operational strategy type projects other than "is there existing congestion?" At this time, H-1 is the major benefactor for management and operational strategies, and consequently is the only real focus. In addition, they have limited analytical tools to assess management and operational strategies.

Responding to Strategic Planning Challenges

Long Range Transportation Plan

Whereas the Hawaii MPO / DOT is deferring maintenance through-out Oahu due to financial constraints, operations and management strategies are preferred for their low cost value. HDOT does not have the money to maintain the roadways on a regular basis, let alone try to expand the system. It has been said that "unless it is an absolutely required capital improvement, all available funding is going to operations and maintenance."

Funding Issues

The region projects stagnant revenues, and certainly not enough to address the present shortage let alone future issues. At most, the MPO projects constant funding levels (2% annual increase in Federal and 1% increase in State and City & County funding), which is not keeping up with inflation.

They need to start focusing more on the right kind of public information and outreach. For example, answering the public question of "how is it that we can afford to spend X billion on a rail system, when we can't even keep the roadways properly surfaced." All three entities need to do a better job of informing the public on appropriate investments and how much money it takes to build roads. They are finding the need to debunk a lot of misinformation about the cost to build infrastructure facilities.

Performance Measures

The Honolulu area does not currently have a performance measure for travel time reliability. In addition, the tools they have available do not have the capacity to measure reliability. Observationally, taking the zipper lanes will yield better travel times and better reliability, but whether the model can predict it with any certainty is doubtful / challenging (using TransCAD).

Multimodal Corridors

Like many metropolitan areas, Honolulu's two initiatives for premium transit service have come to a halt due to financial constraints. The service was from Central Oahu to downtown that was non-stop and provided by a private vendor. This service was terminated at the end of last year for reasons unknown.

A ferry service pilot project from the far end of Pearl Harbor to downtown Honolulu was put into service, but the cost per ride was not a sustainable subsidy the City & County could afford.

Regarding freight service, they are so confined geographically that about the only thing they can do is to work with the Port of Honolulu or the airport to facilitate egress/ingress from their facilities. The situation is very much on FHWA's radar and they'd like to find some way for Oahu MPO and its participating agencies to do things better. Hawaii is the last state to adopt the CVISN and are at least a decade behind in terms of handling commercial vehicle management. When Waikiki was being developed there was no provision for loading docks at the hotels, so trucks take the center lane or the side streets to off-load and cause considerable congestion in the process. They have been considering off-hours loading, but the tourist focus of Waikiki essentially limits what is really realistic in terms of off-hour freight operations.

Model Results

The Honolulu MPO is examining cost/benefit of various scenarios under study for the 2035 RTP Update efforts. They are looking at four capacity expansion scenarios (3 facility-specific scenarios based on Central Oahu, Ewa and Waianae transportation needs), one overall lane mile expansion to arrive at LOS D service on an island-wide basis and two scenarios that deal with HOT lane/tolling and cordon pricing into Honolulu.

They are looking at these varied scenarios to provide a higher level of education to the public on transportation facility options and the true cost of transportation infrastructure.

Houston

Overview

<u>Agencies</u>: Texas Department of Transportation (TxDOT), Metropolitan Transit Authority of Harris County (Metro), Harris County Tollroad Authority (HCTRA), Houston-Galveston Area Council (H-GAC), City of Houston

<u>Years of Experience with Managed Lanes / Active Traffic Management</u>: 1979 - current

<u>Brief History</u>:

- 1979: First HOV lane opens a 9.6-mile contraflow lane for buses and vanpools on I-45N (North Freeway), funded by a $2 million UMTA services and methods demonstration grant. This project and subsequent HOV lanes are operated by the regional transit authority in a partnering agreement with TxDOT.
- 1984: First reversible HOV lane opens on I-10, Katy Freeway, initially to buses and vanpools, and later to 2+ HOVs before raising occupancies back to 3+ (1986) and then demonstrating QuickRide pricing starting in the late 1990s
- 1986-2002: Reversible HOV lanes open on six other freeway corridors, replacing the contra-flow lane 2009: The Katy Freeway is reconstructed and the reversible HOV lane is replaced with four managed lanes operated by HCTRA. The managed lanes are separated by plastic pylons, have multiple ingress/egress locations, two direct access with transit facilities to service express bus BRT, include three toll zones and employ variable pricing on a 24/7 basis. The managed lane implementation included a financial contribution from HCTRA toward the total $2.6 billion rebuild of the freeway.

Population: 3,815,000 (2007)

Congestion: 73% of peak VMT congested, 49% of lane miles congested, 56 annual person hours of delay per peak traveler (2007)

MANAGEMENT PROGRAM DESCRIPTION

THE REGION

The greater Houston metropolitan area contains a population of approximately 5.9 million covering a very expansive region. Traffic growth has historically averaged about three percent annually, with vehicle miles of travel averaging four to five percent. In the past decade, population growth has occurred both within the inner city as both densification and infilling has occurred, as well as in more distant communities that comprise the greater metropolitan region. Urban densities extend from 35 to 50 miles from the inner city on the north, northwest, west, southwest and southeast corridors of the region.

Although Houston was founded as a confluence of railroads in the late 1800s and became a major port city in the early 20th century, it has largely grown up around the automobile wit h a majority of its growth occurring since the 1920s. Houston's first controlled access roadway, the Gulf Freeway connecting Houston to Galveston, opened in 1958 on a previously abandoned interurban right-of-way. By 1970 Houston had a well developed system of freeways radiating from its downtown along with plans for three circumferential loops immediately circumscribing the downtown area, approximately 5 to 8 miles from downtown and 15-20 miles from downtown. Houston's freeway system became the largest in Texas early in its development. HOV lanes began to be added to congested freeway corridors starting in 1979, with 126 lane-miles in operation by 2002. Express bus transit was inaugurated along with HOV lanes, and today express buses and ridesharing accommodate over 135,000 passengers daily. All HOV lanes are currently in the process of being converted to HOT.

In 2009 the eight-county Houston area comprises 12,500 square miles and a population of 5.9 million. Population is forecast to grow by more than 1 million within the next decade and 3.5 million by 2035. The 2008 TIP includes almost $11 billion in transportation investment, of which 52% comes from locally generated taxes and tolls. The region has just started building fixed transit guideways, with an LRT starter line opening in 2002 and four more planned to open within the next five years.

The region's reliance on toll roads represents a growing component of the transportation system looking forward. The Harris County Toll Road Authority (HCTRA) came into existence in September 1983 when Harris County voters approved a referendum by a 7-3 margin to release up to $900 million in bonds to create two toll roads - the Hardy Toll Road and the Sam Houston Tollway, to improve the regional mobility and reduce traffic congestion in the Greater Houston area, an area known for rapid population growth. The need for a county-run toll road system came from TxDOT's budget shortfall and its inability to authorize funding to upgrade the second loop around the city, Beltway 8, which had been on planning maps since the 1950s. The Texas Turnpike Authority turned down the opportunity to improve the road as well, leaving the county to upgrade the road to freeway standards. However, Harris County could not afford to build and maintain a freeway from its general fund. Shortly after the referendum, the Commissioners Court created the Toll Road Authority to administer the construction and operation of the new road system. Then-County Judge Jon Lindsay is generally credited with shepherding the referendum from its infancy to its passage, along with the implementation of the plan for the roadway. HCTRA is a part of Harris County's Public Infrastructure Department and is subdivided into a Services and an Operations Division. While for many years, the Hardy Toll Road never had the traffic that the HCTRA envisioned it would need to turn a profit, the Sam Houston Tollway has more than made up for the lost revenue. The high profit margins on the Sam Houston Tollway allowed the authority to construct its third and fourth toll roads, the Westpark Tollway and Fort Bend Toll Road, both of which opened in 2004. Both of these toll roads have termini in Fort Bend County and are run in conjunction with the Fort Bend County Toll Road Authority. The most recent project of HCTRA is contributions toward TxDOT's construction of managed lanes that run along the median of I-10/Katy Freeway between SH 6 and I-610. HCTRA currently operates 103 miles of toll roads in Harris County and contracts to operate toll roads in adjoining counties. HCTRA and surrounding counties plan on building another 120 route-miles of toll roads over the next 15 years.

Management Strategies Deployed / Studied

The Houston region has embraced a variety of management strategies, most notably HOV lanes for the past 30 years. Early in the region's development, growth and demand outstripped the ability to add sufficient freeway capacity. HOV lanes and mass transit, along with commensurate investments in transit stations and very large suburban park-and-ride lots and ridesharing outreach, helped provide alternatives to congestion. The Houston area still reflects the largest commitment in express bus and park –and-ride investment of any US city. The region's barrier-separated lanes offer a truly reliable alternative, commensurate to a rubber tired commuter rail system that traverses virtually every radial freeway in the region. In parallel to HOV lane development which generally took place through 2002, an aggressive freeway rebuilding and expansion program also occurred. For a number of years between 1985 and 1995, Houston's roadway expansion kept pace with demand and congestion was noticeably reduced.

Traffic management is another TDM component that the Houston area embraced at an early stage. The I-45S Gulf Freeway became one of the first in the nation to test ramp metering and freeway surveillance in the late 1960s and early 1970s. As freeways were expanded and upgraded, reliance on these strategies waned and few ramp meters exist today. A more aggressive "quick clear" incident management agreement was reached in 2005 that had the effect of more efficiently handling minor incidents and coordinating towing services among a wide range of agencies and providers.

Looking forward, all HOV lanes will be instrumented with pricing representing a $70 million investment over the next five years. Future plans are to focus new capacity primarily on new toll roads and managed lanes. Remaining funding will be focused on preservation and rehabilitation projects. While a major investment was made over a decade ago in a regional traffic management center, no active traffic management programs are currently envisioned to augment traditional surveillance and incident management practices. No bus on shoulder or active traffic management studies or other projects similar to Minnesota are underway.

Selection Criteria

There is no formal screening or corridor selection process for management projects. In the past, opportunities for partnering occurred between agencies based on interest, need and resources each could bring to a project. This ad-hoc approach has created some interesting dynamics between agency roles. For example, TxDOT has never operated any of the region's HOV lanes, preferring to formalize an agreement with one of the local agencies (either Metro or HCTRA) based on who was a willing partner to sponsor and implement a managed lane facility. And while the state has a legislatively empowered turnpike authority, all local toll roads have been implemented and operated by local agencies. Capacity expansion is still the primary means the region looks to satisfy growing mobility needs, and there is not comparable screening applied to examine trade-offs between a management strategy and a capacity improvement. Some corridors, like I-10 Katy Freeway in its major investment study and environmental review, included both general purpose expansion alongside the implementation of managed lanes, growing the total cross section from 6 general purpose lanes to an average of 14. This approach was taken because the long-range forecast suggested that even 14 lanes will become congested shortly after the re-built route was opened, hence the desire to preserve some capacity for a higher level of management.

Responding to Strategic Planning Challenges

Long Range Transportation Plan

The TIP includes a wide range of investments in all modes, including fixed guideway transit, general purpose expansion, toll road expansion, conversion of HOV to HOT lanes (from one corridor to all six) and bike/pedestrian improvements along with access management and livable communities land use planning for new development. Absent is a larger focus on operations management or active traffic management, and arterial connectivity. The driving forces in the long range transportation plan reflect agency and market driven needs—completing the regional toll road and transit plan. Barriers being experienced are consistent with other regions: lack of sufficient funding, environmental hurdles, inability to stem increases in delay time, and inability in most corridors to add any more capacity. However, more creative ways to operate the system are still not being focused on.

FUNDING ISSUES

The region has increasing funding due to the investment being made in toll roads regionally. This is partially offset in a loss of funding (in real terms) from the state and federal levels. This reality is why so much focus is being placed on toll lanes and toll roads, along with a profusion of new toll road authorities—one for almost every one of the six surrounding counties.

INTERCHANGES

Up until now, new interchanges have been added or reconstructed by TxDOT as the needs arose. I-10 Katy completely rebuilt four major system level interchanges, partially funded by an infusion of toll revenue HCTRA fronted in a cooperative agreement with TxDOT. However, looking forward, it is apparent in the TIP that only toll facilities with system interface with other routes will likely see interchange ramps built/rebuilt. Most of these examples relate to greenfield toll roads, not managed lanes.

PERFORMANCE MEASURES

Regional performance measures relate to average vehicle occupancies, demand/capacity, delay time, average travel speeds and speed contours for selected employment centers, population/density to lane-miles of roads, person and vehicle hours of delay. These measures are monitored, but not significant in the allocation of resources or determination of the most appropriate investment insofar as traffic management strategies are concerned. In general, these measures are positive for areas of growth were demand can be met with capacity expansion. There are no regional tools applied to measure the reliability of managed lane facilities.

MULTIMODAL CORRIDORS

The region has a rich history of addressing multimodal planning at various levels, both regionally and more appropriately, at the corridor level. Defined solutions attempt to address, or leave space for, both current investments and potential ones. For example, most freeway reconstruction and expansion has left space for at least one reversible managed lane even if there is no apparent agency to implement and operate such a treatment in the exurban areas. Space is being left for future LRT and commuter rail within ROW takes, and transit agency plans include addressing local, circulator and express bus needs along with ridesharing. Investments in transit stations and P&R lots similarly address both multi-modal needs and land use (TOD) opportunities. There are few formal policies supporting these considerations, but instead, close agency relationships in which all attempt to service the future and potential needs of others.

MODEL RESULTS

Cost-benefit studies have been undertaken for selected investments and for specific modes. In particular, there is a rich library of studies and evaluations supporting the first 25 years of HOV lane performance and investment, largely housed within the Texas Transportation Institute (TTI).

MIAMI – FT. LAUDERDALE

OVERVIEW

Agencies: Miami-Dade MPO, Miami-Dade Expressway Authority, Broward County MPO, FDOT Districts 4&6, South Florida Commuter Services, Miami-Dade Transit, Broward County Transit

Years of Experience with Managed Lanes / Active Traffic Management: 14

Brief History:

- 1995 - HOV lanes implemented on I-95
- 1994: Initial partner in FHWA Value Pricing Program
- 1995 – 1999: Conducted feasibility studies of HOT lanes for Metropolis region
- 2000 – 2002: Implemented region's first HOT lane pilot program on I-22
- 2006: Implemented bus use on shoulder treatment along SR 836
- 2007: Submitted proposal and receive approval of Urban Partnership grant
- 2008 : Opening of initial 95 Xpress Lanes on NB I-95 to Golden Glades Interchange
- 2009: Completion of Managed Lanes Study and Plan for FDOT District 6
- 2009: Application submitted to FHWA Tolling and Pricing Opportunities program to obtain funds to develop Managed Lane Network Concept of Operations

Population: 5,420,000 (2007)

Congestion: 82% of peak VMT congested, 71% of lane miles congested, 47 annual person hours of delay per peak traveler (2007)

MANAGEMENT PROGRAM DESCRIPTION

MANAGEMENT STRATEGIES DEPLOYED / STUDIED

- 95 Express Lanes – Phase 1A (Miami CBD to Golden Glades Interchange), deployed and operational in December 2008. Phase 1B expansion (Golden Glades to I-595) scheduled for completion in January 2010. Phase 2 (north of I-595 through Broward County) scheduled to start construction in 2010. The 95 Express is a combined BT/managed lane project, and incorporate a variable toll/congestion pricing strategy
- Express Toll Lanes for I-595 – After I-95 Express, the next corridor for the deployment of managed lanes is I595, involving reversible managed lanes extending from I-75 to east of US 441/SR 7, with direct connections to/from Florida's Turnpike, and connect with the 95 Express at the Golden Glades park-n-ride facility The facility will include new BRT service.
- Variable Tolling on MDX and FTE Facilities - Both MDX and FTE are planning to replace cash tolling with an all electronic toll collection system using a combination of transponder and video tolling. This will allow to introducing peak vs. off-peak differentials in tolls. Open Road Tolling (ORT) will apply to SR 869/Sawgrass Expressway in Broward County, the Turnpike mainline in Broward and Miami-Dade Counties, the Homestead Extension of Florida's Turnpike (SR 821/HEFT), and four MDX toll roads (SR 836/Dolphin Expressway,

SR 112/Airport Expressway, SR 916/Gratigny Expressway, and SR 874/Don Shula Expressway. These ORT roadways may become variably priced roadways in the future.

- Express Toll Lanes on Selected Toll Roads - Both MDX and FTE have carried out feasibility studies on the addition of value-priced express toll lanes on SR 836 and SR 821. These studies have included that managed lanes would be the most cost-effective way to add capacity to these corridors, though portion of these lanes would need to be elevated. Because of the high traffic connection between SR 836 and 821, the plan is to implement express toll lanes on these facilities at the same time. This would occur after the conversion to Open Road Tolling and peak/off-peak pricing scheme has been instituted.
- Addition of Managed/Express Toll Lanes on Other Regional Roadways – Reversible express lanes are being studied on I-75 between I-595 and SR 826/palmetto Expressway, as well as adding HOV lanes to the Palmetto Expressway. Miami-Dade County is also studying a managed lane project on US1 South utilizing the existing South Miami-Dade Busway Corridor.
- Toll Truck Lanes - A study was conducted to assess the feasibility and configuration of a truck toll lane system in Miami-Dade County. Two major connections were identified on the County expressway system, to get trucks from the Port of Miami to the Golden Glades Interchange area and Miami International Airport: 1) I-395 and I-95 from the new Port Tunnel to Golden Glades, and 2) SR 112/Airport Expressway from I-95 to Ludlum Road.

These management strategies have been reflected in the latest (year 2035) regional transportation plans for Miami-Dade and Broward Counties. The broader managed lane network is referred to as the South Florida Express. The intent in both MPO plans is to address added capacity and improved level of service through a combination of managed lanes and new BRT service in all of the freeway/tollway facilities in these two counties. The South Florida region sees an integrated strategy, with active traffic management and enhanced transit service (in particular, BRT) applied in the different corridors.

SELECTION CRITERIA

For FDOT District 6, a Managed Lanes Visioning Study was conducted for Miami-Dade and Broward Counties., completed in 2009. This study addressed managed lanes and premium transit service integration to both expressway and major arterial corridors within the two counties, for the South Florida Express system. This is being followed up by the development of a Network Concept of Operations for the South Florida Express. This will identify and involve regional stakeholders, determine common goals, objectives, vision, system approaches, concepts, and operational strategies for facilitating the subsequent design and deployment of the managed lanes system. Key topics to be addressed in the Network Concept of Operations will include:

- Refined relationships among the various FDOT districts, other transportation agencies, and the local/regional Traffic management Centers.
- System requirements for a regional network, such as developing consistent messages and familiar signage throughout the network to avoid traveler confusion.

- How to integrate already developed concept of operations, public agency programs, multi-agency tolling initiatives, traffic operations initiatives, law enforcement, and incident and emergency management operations and interfaces
- How should a multi-agency regional network be administered, operated, and maintained – tolls and traffic/transit operations.
- Develop a refined set of performance measures and monitoring for a region system.

RESPONDING TO STRATEGIC PLANNING CHALLENGES

INTERCHANGES

The 95 Express project has involved some interchange modifications to provide direct access in and out of the managed lanes. With the South Florida region being built out, interchange improvements in future will focus on modifications to freeway to freeway interchanges to accommodate a seamless transition of managed lanes between facilities, and rebuilding certain interchanges to provide for greater safety and limited capacity improvements.

PERFORMANCE MEASURES

A detailed set of performance measures (over 40) was developed for use in the evaluation of the 95 Express project. Measures were developed addressing 1) System Impacts/Utilization 2) Operations and 3) Acceptance/Satisfaction. Impacts on both managed and general purpose lanes were identified, as well as transit operations. This measurement system as applied to other corridors and the South Florida Express system as a whole will be refined in the development of the Concept of Operations for the regional system.

SAN FRANCISCO / OAKLAND BAY AREA

OVERVIEW

Agencies: Metropolitan Transportation Commission (MPO), California Department of Transportation (Caltrans), Congestion Management Authorities (CMA) – county-based entities who aggregate municipal activities for regional congestion reduction and mobility enhancement

Years of Experience with Managed Lanes / Active Traffic Management: 1970 - current

Brief History:

- 1970: HOV Express Lanes opened on the Bay Bridge Toll Plaza, establishing concurrent flow design of HOV facilities
- 1974 - current: Concurrent flow, peak-hour only HOV lanes are opened on 51 distinct segments throughout the Bay Area.
- 1994 - 1997: Initial partner in the Federal Congestion Pricing Pilot Program, examining application of value pricing to the Bay Bridge for congestion management
- 1996 - current: Various endeavors / studies by Alameda County for the development of HOT Lanes in the County; I-680 HOT lanes currently under construction (first Bay Area HOT lane to open in 2010)

- 1999 - current: Study of HOT lanes for US 101 in Marin / Sonoma Counties; still examining HOT lane / toll viability for the corridor
- 2001 - current: Santa Clara County pursuit of HOT lanes throughout the San Jose area. Initial HOT lanes under development for SR-237 / I-880.
- 2004 – 2007: MTC conducts Freeway Performance Initiative study to address phasing of operational / management strategies for the region
- 2006 – current: MTC conducts a regional HOT lane assessment project
- 2007 – current: San Francisco County signs an Urban Partnership Agreement with the US DOT for pursuit of congestion pricing, bus rapid transit, and other strategies for San Francisco. Pricing on Doyle Drive is dropped in favor of a parking pricing program in San Francisco.

<u>Population:</u>

- San Francisco/ Oakland: 4,480,000 (2007)
- San Jose: 1,705,000 (2007)

<u>Congestion:</u>

- San Francisco/ Oakland: 82% of peak VMT congested, 60% of lane miles congested, 55 annual person hours of delay per peak traveler (2007)
- San Jose: 81% of peak VMT congested, 68% of lane miles congested, 53 annual person hours of delay per peak traveler (2007)

Management Program Description

Management Strategies Deployed / Studied

The Metropolitan Transportation Commission (MTC), California Department of Transportation (Caltrans), and respective county-based Congestion Management Agencies (CMA) have worked over the past twenty years towards reorienting highway investments towards sustainability. The principal tool for evaluating the effectiveness of operational and management treatments for planning purposes has been the Environmental Impact Record (EIR), where any given project must be evaluated against a variety of discrete operational, highway capacity, and transit alternatives. Typically, the system management alternative invariably performed the best.

Recently, in attempting to move the bar forward, the MTC (in partnership with Caltrans and the CMAs) attempted a comprehensive review of operational / management strategies on a corridor-by-corridor basis, called the Freeway Performance Initiative (FPI). The FPI created prioritized list of system management and capital investments for each corridor. From this list, a comprehensive benefit / cost analysis was conducted and prioritization / phasing. For example, for a corridor with a long-term projected need for managed lanes, an auxiliary lane might have been recommended as an interim measure to "buy some time" until the managed lane implementation was warranted and funding was available. By comparison, other corridors may have overwhelming need. The FPI study created prioritized lists that were incorporated by the MTC (the MPO for the region) and agreed upon by the CMA's (the implementing agencies).

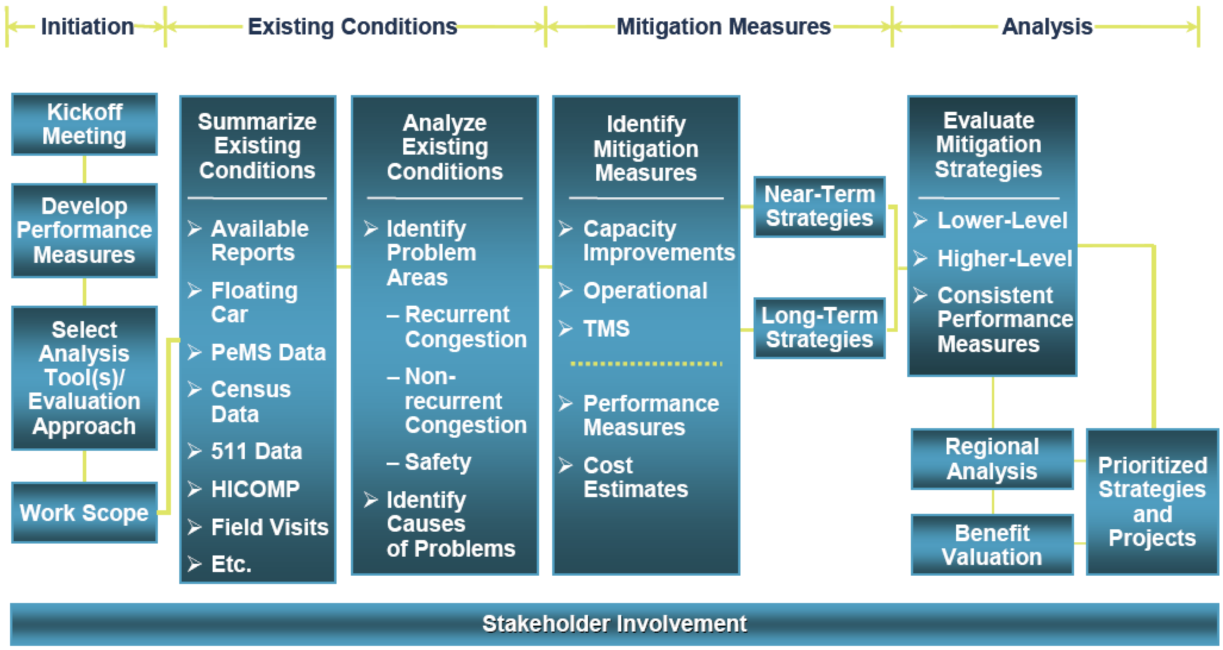


FIGURE 4: OVERVIEW OF FPI CORRIDOR ANALYSIS APPROACH, METROPOLITAN TRANSPORTATION COMMISSION, 2007.

In addition to the FPI study, the MTC also conducted a regional managed lane network plan, building upon existing efforts towards implementation in Alameda and Santa Clara Counties. MTC, working with its regional partners, has developed a detailed cost-effectiveness analysis on a corridor-by-corridor basis. Although this managed lane network has moved forward for implementation, it regrettably has not yet been incorporated within the framework of the FPI. Subsequent efforts by MTC will concentrate upon integrating the managed lane concept into the detailed phasing of FPI strategies.

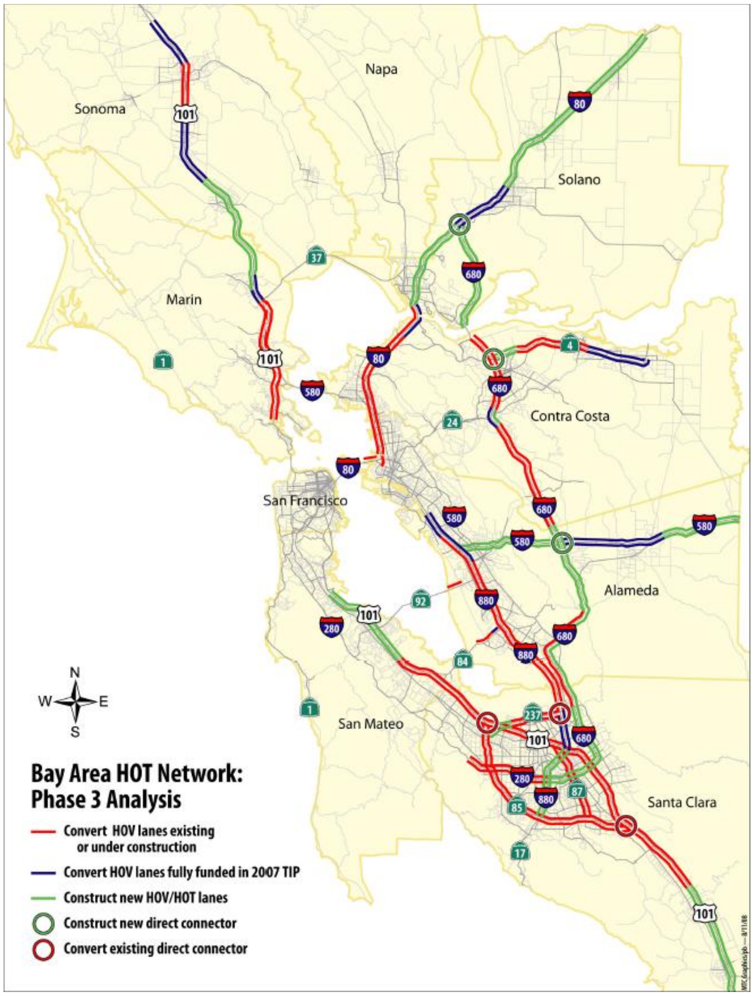


FIGURE 5: REGIONAL MANAGED LANE SYSTEM, METROPOLITAN TRANSPORTATION COMMISSION, 2009.

Selection Criteria

The FPI Study completed a quantitative screening of corridors, projects, and strategies. The Metropolitan Transportation Plan (MTP) then rolled up the measures of effectiveness for regional impacts to vehicle miles traveled, travel time delay, air quality / greenhouse gas emissions, etc. as evaluated in the travel model. The regional managed lanes study also examined traffic and air quality benefits when developing the regional system. Commons measures included vehicle hours traveled reduction, peak hour average speed increase, reactive organic gasses reduction, nitrogen oxide reduction, PM10 reduction, and CO2 reduction.

Responding to Strategic Planning Challenges

Long Range Transportation Plan

The FPI Study (and following process) has fundamentally changed the way that MTC deals with the MTP, the long range transportation plan for the region. The FPI provided a recommended list of priorities, from which the CMA's submitted their project priorities to the regional plan. This was compared back to the FPI recommendations, in order to ensure consistency between the short-term phasing of the FPI and the long-range vision of the MTP. The FPI, in essence, creates a phasing mechanism in the MTP, showing iterative steps in the long-range plan. This prevents big-capacity projects from "grabbing the limelight" in the MTP, and instead shows the operational and management treatments that must occur first before capacity expansion would be considered. MTC had some occasional differences from the CMA's in terms of priorities, but the long-range timeframe of the MTP allowed those differences to dissipate.

In the development of the MTP, the FPI process recommendations reflected a consistent assessment of management and operational treatments across corridors, normalized performance criteria to account for differences in detail of data, the desire to close managed lane gaps in the corridor, and the presence of heavy freight, developed a robust benefit-cost framework for planning analysis, and developed a phasing plan through the life of the MTP.

Funding Issues

Although the region does project declining transportation revenue from known sources, historic evaluation indicated that California had a history of providing unanticipated "bumps" in revenue over time. These bumps typically came from voter action, state investments, etc. that are unspecified and certainly cannot be relied upon for the future. However, the MTC did make an effort towards identifying how future unspecified funds would best be applied in the region. Although no policy has yet been determined, one possibility is to view managed lane revenue from tolls much in this context, even though the money is designated to managed lane projects. In turn, funding for other efforts will be guided from this process.

There are some big projects in the region, but most of the large capacity projects are already funded through tolls (primarily bridges). Two big exceptions are the Marin Narrows and Doyle Drive, both of which the region has aggressively pursued federal and other funding for assistance. The region, unofficially then, has internalized the costs for big projects by generating separate revenue through tolls to accommodate those big projects.

Interchanges

An interchange is examined within the context of the FPI, and is subject to the same analysis.

Performance Measures

The principal performance measures concentrate upon three areas: mobility (movement of people and freight), reliability (predictability of travel time), and safety. Mobility measures in the FPI are travel time and travel delay, with separated analyses for managed lanes and general purpose lanes. Reliability is measured by a "buffer index", which defines the extra time cushion that travelers add to their average travel time when planning trips at the 95^{th} percentile. MTC applied the FHWA guidance on buffer indexes for the FPI. Safety measures comprise crash reduction rates, with delineation between fatality, injury, and property damage crashes.

Multimodal Corridors

Neither the FPI study nor the managed lanes study explicitly addresses transit use on the corridors. However, the region's extensive history of HOV lanes has been a component in the development of managed lanes. Already, some corridors are sufficiently congested so as to require HOV-3+

operations (I-80 primary among those). Additional HOV lanes will soon reach their design capacity with HOV-2+ operations. As a result of the anticipated needs, the MTC has adopted a policy of transitioning to HOV-3+ operations on the managed lanes system as situations warrant and/or as necessary to meet targets for O&M and revenue recovery for new facilities.

Model Results

The region has adopted a life-cycle benefit-cost analysis to assess the effectiveness of the region's FPI and managed lane recommendations. The benefit-cost analysis reflected changes from current (2007) conditions for short-term improvements (2015) and long-term improvements (2030). For comparability, the analysis assumed all projects were begun in 2007, which is unreasonable for a variety of factors. The lifecycle analysis reflects upfront costs (capital, support, ROW) and ongoing O&M costs. Prioritization of projects within corridors and for the plan's phase increments are dependent upon value-added strategies that consistently yield a beneficial relationship in the B-C analysis.

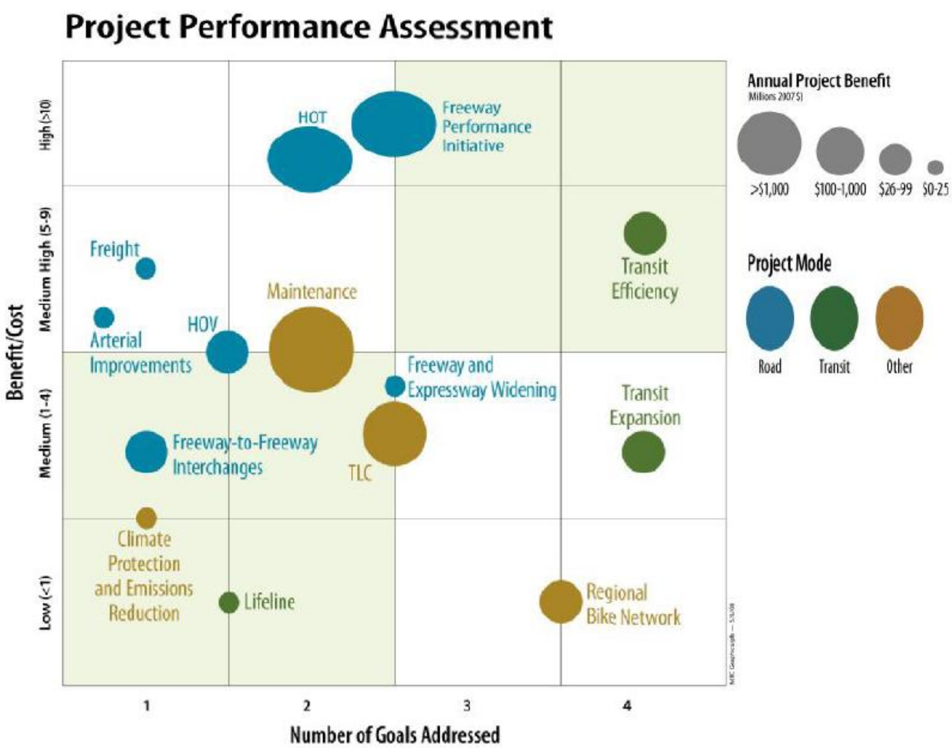


FIGURE 6: MODELED COST-EFFECTIVENESS FOR 2035 PLAN, METROPOLITAN TRANSPORTATION COMMISSION, 2008.

Seattle

Overview

<u>Agencies</u>: Puget Sound Regional Council and Washington State Department of Transportation

<u>Years of Experience with Managed Lanes / Active Traffic Management</u>:

- Managed Lanes: mid-70's to current
- Traffic Management/ITS: mid-70's to current
- Active Traffic Management: feasibility studies (2007 – 2009), 2010 speed harmonization & queue warning system on-line

Brief History:

- 1970s – 1980s: Inclusion of HOV lanes, park-and-ride lots, and ramp meters in the interstate definition.
- Early 1990's: WSDOT Core HOV System Plan
- 1992 WSDOT Freeway HOV System Policy
- 1997: WSDOT Puget Sound HOV Pre-Design Studies
- 2001-2005: Vancouver HOV Lanes Pilot Project
- 2004: I-405 Managed Lanes White Paper
- 2006: Hours of Operation Demonstration Project
- 2006: Comprehensive Tolling Study Part 1
- 2007: I-405 Managed Lanes White Paper Update
- 2008: Comprehensive Tolling Study, Part 2
- 2008: SR 167 HOT Lanes Pilot Project Opens
- 2007 – current: Pursuing active traffic management system of speed harmonization and queue warning system and inclusion of ATM measures in the Highway System Plan.
- 2008 – current: Seattle (Lake Washington) Urban Partnership Agreement (congestion pricing, ATM elements, transit improvements and TDM measures)
- 2009 – current: Value Pricing Pilot Program, Acceptance and Awareness of Pricing Study

Population: 3,100,000 (2007)

Congestion: 66% of peak VMT congested, 51% of lane miles congested, 43 annual person hours of delay per peak traveler (2007)

Management Program Description

Management Strategies Deployed / Studied

The Seattle region has deployed an extensive variety of management and operational strategies:

- HOV Lanes – Extensive HOV system through-out the greater Puget Sound Region (totaling approximately 250 lane miles as of 2009). WSDOT developed the Core HOV System Plan in the early 90's that identified 310 HOV lane miles on I-5, I-405, I-90, SR 520, SR 509, SR-167, and SR 16. Direct Access Ramps and Freeway to Freeway connectors were identified as part of the HOV Pre-Design Study in 1995/1996.

- Reversible Express Lanes – I-5 between Northgate and the south end of the Seattle CBD (approximately 7.5 miles in length). I-90 between downtown Seattle and just east of I-405 (approximately 6 miles in length).
- HOT Lanes – Implemented first HOT lane facility on SR 167 in May 2008. Looking to implement additional HOT lanes on re-built SR 520 Bridge and I-90, as well as the length of I-405 (30 miles).
- Tolling – Originally used to finance bridges (I-90, SR 520 and Tacoma Narrows). New Tacoma Narrows Bridge is currently tolled. Urban Partnership Agreement for SR 520 will include variable tolling. The Puget Sound Regional Council (PSRC) recently completed a demonstration on GPS-based regional tolling.
- Traffic Management Centers, extensive use of ITS, incident management, ramp metering.
- Limited use of transit only lanes.

In addition to the deployed strategies, activities in the region have emphasized the role of operational and management strategies for addressing mobility needs:

- The Washington State Department of Transportation (WSDOT) has the Moving Washington Program. This congestion reduction program has identified 3 key strategies: operating the existing system efficiently, adding strategic road capacity and managing demand by providing choices. In addition to the over-arching strategies – the plan includes integrated corridor specific plans to address location specific situations.
- Washington State Transportation Commission conducted a statewide tolling study – recommending 7 potential tolling corridors (Cross Lake Washington, I-5 Central Puget Sound, I-405/SR 167, I-5 Lewis County, SR 395 N Spokane, Columbia River Crossing and Snoqualmie Pass).
- PSRC convened a Pricing Task Force to engage business and policy leaders on tolling
- Generally, PSRC's RTP is more towards balancing management of existing system and strategic investments in expansion.
- WSDOT recently received funding to develop implementation plans to convert their HOV system into tolled express lanes.
- The HOV system is largely completed and Surveillance, Control and Driver Information (SC&DI) elements were included in HOV lane construction projects.
- Large-scale freeway expansion hasn't really been seriously looked at in a very long time. However, there is still political interest in extending SR 167, widening I-405 and the construction of the Cross-Base corridor/freeway. But there is also a lot of political interest in limited to no freeway expansion either. In certain instances, local jurisdictions are interested in expanding their arterial systems leading to the freeway/highway corridors, but have been somewhat resistant to the creation of a network of parallel facilities to provide redundancy to the freeways.
- Destination 2030 had more roadway projects in the fiscally constrained version than is being considered for Transportation 2040, partly due to climate change initiatives.
- Major capacity expansion projects are being looked at for tolling (tolled (SR 509, SR 99, CrossBase) and in other instances transformed to BAT and managed lane concepts.

- The current direction seems to be an incremental approach starting with tolling project level facilities and then moving to full system tolling on the freeways and eventually VMT charges (2040). Will incrementally move to VMT charges.
- Upcoming tolling studies by WSDOT include: Express Toll Lanes (2) on I-405 in Central Puget Sound, SR 99 Alaskan Way Viaduct Replacement Project, I-5 Columbia River Bridge Replacement in Vancouver Washington and toll feasibility studies for freeway extensions on SR 167 and SR 509 (south Puget Sound).
- In the past 10 years or so WSDOT has been more focused on mega projects, but WSDOT also continues to layer on additional management systems one at a time (see brief history) to create a more manageable and safer traffic flow.
- PSRC has an extensive benefit-cost analysis tool for use with their model. An econometrics model that builds off of their land-use and transportation model. Have been using this to explain the benefits of a more localize project to the greater region….gets at the sub-area equity issues.

Selection Criteria

The HOV program was screened and selected as noted previously in the early/mid 90's. Generally the screening criteria related to whether there was transit service, how bad the congestion was, the expected benefits, but implementation and construction was a bit more opportunity based. Managed lanes implementation has been opportunity based thus far (SR 167), however, a system plan is being developed and future projects will flow out of that process.

WSDOT recently completed a feasibility study for ATM and have a general implementation plan for a proposed speed harmonization and queue warning system for the Central Puget Sound Region.

PSRC is reporting out on managed lane travel-times for certain facilities (O/D pairs) in order to do roadway travel time as well as transit travel times. The agency has reviewed different scenarios – some heavy on capacity expansion, some on system management, and others on tolling. Transit congestion and roadway congestion are the primary indicators. The PSRC has divided the region into 12 broad transportation corridors and is compiling existing data and information for each to generally describe the transportation system and the expected or projected need for the future.

Responding to Strategic Planning Challenges

Long Range Transportation Plan

The PSRC still identifies deficiencies based on level of service, providing a bias towards expansion. Low cost/high benefit items will likely be scoped into a larger or broader improvement project. For example, HOV system projects would also include interchange improvements or SC&DI elements. The region has identified bottleneck fixes in all corridors and they tend to rise to the top; but overall, the lack of funding has maintained the focus on bottlenecks.

All arterial ITS and signal coordination improvements have been put into the constrained plan (not the unconstrained plan) as a must-fund activity. The LRTP is still determining how to fund the plan, including looking for the tolling projects to then fund the low cost/high benefit activities (if you toll SR 520, can those funds be used towards ATM type projects/activities). The first round of analysis looked at higher amount of transit investment, focused much more on High Capacity Transit infrastructure, rather improvements in localized transit. PSRC worked with the transit agencies to include more bus service at higher frequencies in the system, which could eventually transition to HCT.

On the whole, ITS has not been the most popular strategy by planners in the region, so PSRC has been trying to package it with other elements like TDM and transit when applicable. There is a lot of general support for more ITS type projects, but not one of the signal coordination projects was selected as part of the TIP. PSRC is trying to determine how to bring this into focus and obtain funding for these types of elements.

Funding Issues

Transportation funding has been decreasing and a funding shortfall is projected if the current funding strategy is maintained. The PSRC has started to include tolls and user fees as part of the funding scenario for Transportation 2040. In the initial years there is an assumed increase in the gas tax, with a transition to corridor tolls, and then to full system tolling, and eventually to VMT-based fees. Current funding for the 30-year baseline for the Regional level (based on currently levied taxes) is as follows: 66% goes to transit, 25% to local jurisdictions, 10% goes to state highways. The preferred alternative going forward could have a different distribution.

Interchanges

WSDOT has identified 22 direct access ramps/freeway-to-freeway connectors and 14 in-line freeway stop needs in the late 90's. Generally, the identified freeway-to-freeway interchanges are so dramatically expensive, that they are screened out most of the time, unless it is concerning a freeway with room in the middle. Sound Transit funded approximately 10 direct access ramps (1 in-line freeway station) as part of their Regional Transit Plan. But determining who is responsible for building the interchange oriented facilities is challenging and funding tends to make them prohibitive.

WSDOT has tried other design options for freeway-to-freeway connectors, by constructing a center to outside lane flyover prior to the interchange ramps to allow transit and carpools to utilize the interchange ramps to make the movements (I-90).

Working with PSRC, WSDOT has identified bottleneck and chokepoints in the system that will be included in the financially constrained plan (which means that WSDOT thinks they can fund those interchanges).

Performance Measures

At the policy level, travel time reliability is recognized as an issue and WSDOT has actually tried to measure it as a function of congestion, but it is difficult to measure using the regional model. Travel time reliability is very important in the evaluation of alternatives. And PSRC is in the midst of updating and increasing the specificity of performance measure for Transportation 2040. Vision 2040 provided some general measure directives (high level) and also set up criteria that were to be run through the benefit/cost model. PSRC is working to design performance metrics that align with the Vision 2040 policies that are based on the regional goals. PSRC is working to use the framework of the congestion management process and expand it to include the ability to assess service levels for other modes or needs, like freight and non-motorized travel, etc., for the 12 identified corridors. The performance metrics are probably going to be more extensive and include more varied measures.

Multimodal Corridors

WSDOT has been very explicit in their policies that they have a priority system on the freeways for transit. There is a whole series of HOV policies in place and some specific projects have made commitments, but the details of how it gets done and how everything plays out is more complex. For example the I-90 memorandum of agreement, is probably the most explicit in that the express lane speeds had to maintain a 45mph speeds; if not, the Mercer Island bound traffic (allowed SOVs) would no longer be able to use the express lane facilities, if 45 mph speeds were not maintained, then carpools and vanpools would be restricted and the facility would become transit only. And policy for the HOV system as a whole has a 45mph for 90 percent of the time understanding, but in many instances in the region, the system is overwhelmed and does not function at 45mph. But evicting the 2+ HOVs will cause other problems. The details of moving a managed lane system is being discussed (who can buy in, who is free, etc), and may be included in the RTP as an interim strategy. PSRC's Vision 2040 has an emphasis on providing transportation choices that compete with the SOV.

4.0 Findings

The principal finding from this effort indicates that the Minneapolis – St. Paul metropolitan area is not alone in recognizing there are insufficient funds to undertake major capacity improvement projects to meet anticipated travel demand. The Twin Cities has identified a preference for incorporating operations and management strategies into its long range transportation plan. In many ways, this policy preference reflects a more "European" approach to traffic management; however, other U.S. metropolitan areas are also relying on management and operational strategies to address anticipated traffic congestion and growth in travel demand. The primary difference between the U.S. implementation, including that of the Twin Cities, and European experience is the U.S. dedication of one or more managed lanes of travel for free-flow condition maintenance. Despite this difference, the broad implication is that urban areas across the developed world are increasingly investing in demand and system management strategies that emphasize operational performance rather than broad system capacity.

Management Strategies Deployed

Operations and management strategies have been actively pursued to one extent or another by many peer communities. Of particular interest in the Twin Cities region are those applications that provide a long-term return on investment, so as to provide a credible alternative to unaffordable capacity expansion. These strategies would be expected to enhance traffic operations through flow maximization, improve person throughput through increases in average vehicle occupancies and transit ridership, reduce incidents and crashes, and improve travel time reliability. To accomplish similar objectives, other communities have pursued managed lanes (common in the U.S.) and active traffic management (common in Europe). Managed lanes have many operational variants, including occupancy allowances, time-of-day restrictions, vehicle-type restrictions, and congestion pricing. In the United States, common types of managed lanes are HOV lanes, HOT lanes, Express Toll Lanes, and limited-access express lanes. Active traffic management as deployed in Europe attempts to regulate the flow of all vehicles across all lanes of traffic through the implementation of speed harmonization, queue warning, lane controls, junction controls, dynamic rerouting, and dynamic travel time information.

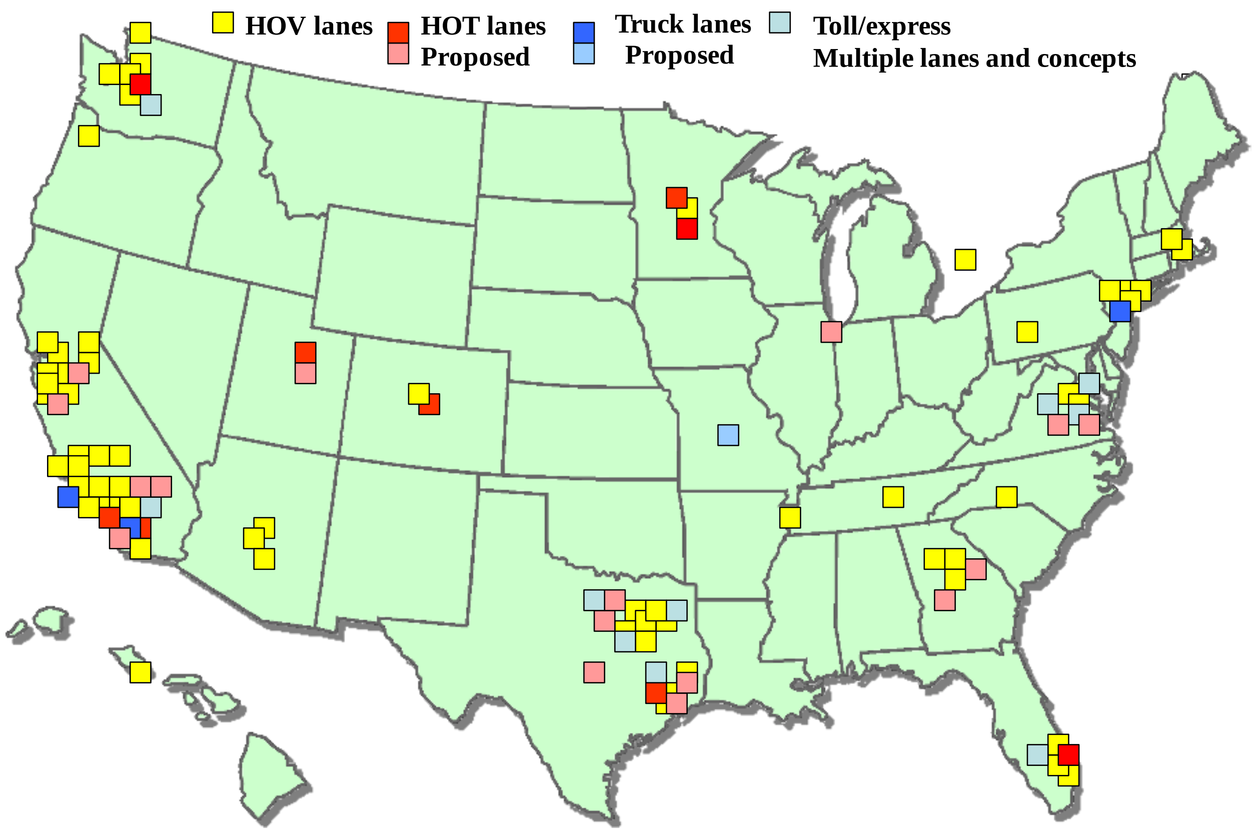


FIGURE 7: U.S. MANAGED LANE PROJECTS, PB, 2009.

Managed lanes have been proposed and implemented throughout the U.S. Although the ten years between 1996 and 2005 yielded only five operational managed lane facilities, the past four years (2006 – 2009) have witnessed six new facilities open, with an additional nine under construction. The managed lanes adopt a variety of access and eligibility policies; indeed, there is no standard for the phrase "managed lanes", as each implementation is slightly different than another. That said, a principal finding of this effort is that not only are managed lanes becoming an increasingly important component of U.S. freeway operations, but for many regions, managed lanes have become a featured component for addressing long-term capacity constraints in a corridor.

CORRIDOR/STRATEGY SELECTION CRITERIA

The nature of managed lanes in certain communities has evolved from a short-term, corridor-specific, operationally-focused strategy to a long-term, system-wide, mobility-focused strategy. Although project development still occurs at a corridor level for managed lanes, capacity planning and systems integration are increasingly conducted at a regional / system level. In this context, managed lanes are often considered side-by-side with active traffic management.

For example, in the San Francisco Bay Area, a comprehensive phasing plan has been developed for the development of not only managed lanes, but also ATM (called the "Freeway Performance Initiative"). In a few corridors, managed lanes are implemented concurrent with ATM to provide better traffic management. In this context, the Bay Area generated a prioritized list of system management and capital investments for each corridor. From this list, a comprehensive benefit / cost analysis was conducted and prioritization / phasing completed. For example, for a corridor with a long-term projected need for managed lanes, an auxiliary lane might have been recommended as an interim measure to "buy some time" until the managed lane implementation was warranted and funding was available. By comparison, other corridors may have overwhelming need. Similarly, Dallas – Fort Worth's policy endorsing toll road viability has yielded a system-wide approach to implementing managed lanes. Both metropolitan regions envision managed lanes as the principal capacity expansion function for the 20-year long range plan. Regrettably, besides these two communities, no formal screening or corridor selection process has been adopted on a system-wide basis for management projects. Instead, it is determined by short-term prevailing corridor characteristics – such as the existence of underutilized HOV lanes or the desire to augment revenues for capacity expansion.

Integration with Regional Transportation Planning

There is no established guidance for the incorporation of management and operational strategies within the context of the long-range plan. Indeed, the development of the long-range plan as a 20- or 30-year snapshot of the future network is inherently biased towards identifying capacity improvements. Ongoing operations and management of freeway corridors is not easily represented in the narrative of a future network. Although many communities have attempted to incorporate managed lanes within the long range plan, these projects are often simply identified as an alternative line on a map compared to a capacity expansion.

The one exception to this practice is the San Francisco Bay Area, which has fundamentally changed the development of the long range plan through the Freeway Performance Initiative. The FPI created a system-wide evaluation of regional project priorities, but developed the list of priorities in partnership with the project sponsors. Thus, when projects were proposed for development or inclusion with the long range plan, the phasing of the project in the FPI determined its suitability for inclusion. If iterative steps (as identified in the FPI) were not conducted first, the project was not included. This prevents big-capacity projects from absorbing regional funds. Furthermore, it shows a preference for operational and management treatments that maximize the use of available capacity before new capacity is added to the system.

Funding Programs

A common element amongst all peer communities is an active avoidance of "big infrastructure" projects from absorbing identified and anticipated regional funding. Big infrastructure projects include bridges, tunnels, and interchanges that exist within a constrained environment, making substantive improvements and/or capacity enhancement cost prohibitive. In such cases, many urban areas (such as the Seattle, Dallas-Fort Worth, and San Francisco-Oakland regions) have established a policy preference for evaluating and implementing user-based financing as a means of paying-down the cost of these facilities. In most cases, these big infrastructure projects involve tolls across all lanes of traffic into perpetuity, providing a base of funding for the large capital outlay and for lifecycle considerations for operations and maintenance. In all cases, the intent is to prevent these structures from absorbing available highway trust fund revenue for large periods of time.

Outside of big projects, tolls remain an important force for infrastructure development. In Texas, the legislature provided a range of new transportation financing options for regional MPOs to consider in funding needed infrastructure. These tools include loans from the state infrastructure bank, local community-financed shadow-tolling, traditional toll financing, and public-private partnerships allowing for private activity bond financing and comprehensive development agreements. Other states have also enabled greater use of private-sector and toll financing for infrastructure. Unlike the big infrastructure projects, in most applications, tolls are to be applied for new lanes of traffic only or on converted HOV / shoulders.

In the project development process, toll viability screening has been successfully used to ensure revenue production possibilities are examined to complement public revenue. For example, the Dallas-Fort Worth region evaluates all new highway capacity using federal aid funds for toll road viability. Since adoption in 1993, the region expanded the policy to include express toll lanes and managed lanes. As a result, the region has an extensive projected network of toll and managed lanes facilities, with little new "traditional highway" capacity due to be constructed, unless it is concurrent with new toll lane capacity (such as improvements to frontage roads).

An interesting development witnessed in various metropolitan areas is the extensive use of regional partnerships to implement operational and management strategies for congested freeway corridors, and, to deliver new managed lane capacity projects. Although financing is a key consideration within the development, it should be noted that this extends beyond financial considerations. Partnerships with regional / county authorities, as well as non-profits (transportation management associations) and private-sector enterprises, have helped bring projects to fruition quicker and with greater regional concurrence.

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Active Traffic Management

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APPENDIX G: PERFORMANCE MEASURES TECH MEMORANDUM

4/13/2010 v3

Technical Memorandum #2: Performance Measures

Metropolitan Highway System Investment Study

Parsons Brinckerhoff

TECHNICAL MEMORANDUM #2: PERFORMANCE MEASURES

Metropolitan Highway System Investment Study

INTRODUCTION

This memo provides a basis of understanding regarding recommended performance measures to be considered in the evaluation of the Metropolitan Highway System Investment Study (MHSIS) alternatives.

The framework for MHSIS performance measures provides evaluation guidance for corridor-based alternatives, including the designation, design, and components of management strategies upon the highway system. To measure the impact of the congestion management strategies, it is essential to make comparisons between alternatives and to a baseline – often know as a "build" and "no-build" concept comparison. This necessity lends itself to quantifiable measures of effectiveness that allow for comparability. Also important is establishing as many common measures as possible that can be used for all corridors and strategies, to enable comparison of findings across the concepts. As this effort will only examine two time points – 2030 and 2060 – the eventual strategy evaluation will lack the ability to track incremental performance over time. Thus, the performance measures may not represent cumulative costs and benefits over the life of the treatment.

TRANSPORTATION POLICY

The *2030 Metropolitan Transportation Plan* provides the policy basis for the analysis of the MHSIS. Within the Highway Vision component of the plan, the following is put forward as the regional guiding policies:

The region faces hard choices in addressing mobility, safety and preservation needs. To respond effectively, the region needs a transportation strategy that is realistic, innovative and focused on leveraging available dollars for the most benefit. The transportation system must optimize all available transportation modes – highways, transit and others – and coordinate them for maximum effect.

Adequate resources must be committed to the preservation and maintenance of the extensive highway system built over the last 50 years, including the bridge repair/replacement program mandated by the 2008 Legislature. It is also important, however, to improve the performance of the highway system in order to preserve essential regional mobility levels for the region's economic vitality and quality of life.

While traffic congestion impacts can and should be mitigated, physical, social and environmental constraints as well as the limited funds available for capacity expansion must be recognized.

Three major objectives to mitigate congestion on the region's roadway system and enhance its performance should be pursued:

- Increase the people-moving capacity of the metropolitan highway system while reducing future demand on the system.
- Manage and optimize, to the greatest extent possible, the existing system.
- Implement strategic and affordable capacity expansion projects.

In order to achieve the above objectives, this plan recommends the following strategies:

- Encourage the use of alternatives to the single-occupant vehicle and changes in travel patterns such as high-occupancy vehicle (HOV) and high-occupancy toll (HOT) lanes, bus-only and priced dynamic shoulder lanes, roadway pricing and other transit advantages.
- Implement low-cost/high-benefit highway construction improvements, including some capacity expansion projects, on a system-wide basis to improve traffic flow by removing bottlenecks, improving geometric design and eliminating safety hazards.
- Reassess the scope and cost of proposed major highway expansion projects to bring them more in line with projected highway revenues and to enhance Mn/DOT's ability to implement them.

In 2009, Mn/DOT and the Metropolitan Council will complete a Metropolitan Highway System Investment Strategy (MHSIS) to refine in greater detail this highway vision, identify low-cost/high-benefit projects along congested highway corridors and reassess major expansion projects. Also in 2009, Congress is expected to authorize a new six-year federal transportation funding bill, providing greater certainty about future highway funding levels. Additional infrastructure funds may also be included in an economic stimulus package.

The MHSIS, coupled with refined financial projections, will permit a better definition of the highway improvement projects to be implemented by 2030. The result of this analysis will be incorporated as an amendment to the Transportation Policy Plan in 2010.

Emerging needs in the developing portions of the region, including new principal and "A" minor arterials, new/rebuilt interchanges and new river crossings, must also be acknowledged in spite of current financial constraints.

Guiding Principles

The November 18th, 2009 document, *Metropolitan Highway System Investment Study: Policy Direction and Guiding Principles*, prepared by the Metro District of the Minnesota Department of Transportation (Mn/DOT) and the Metropolitan Council, served as the basis from which to develop the performance measures. That document reiterated a conclusion from the *Principal Arterial Study*: "a lower-cost/high-benefit approach may be an effective way to address specific problems and that pricing can provide an alternative to manage congestion and for managing congestion." From this conclusion, the MHSIS Project Management Team developed a series of guiding principles, leveraging policies as stated with the regional Transportation Policy Plan and Statewide Transportation Plan. In effect, these principles reorient the long range transportation plan towards projects that maximize the return on investment from existing infrastructure and strategically invest in new infrastructure to meet a constrained financing and construction environment.

The guiding principles applicable to the evaluation of alternatives are summarized as:

- *Utilize the most cost-effective operational and management techniques to optimize system performance*. In effect, this principle states that system and demand management strategies will be prioritized over new capacity for mobility improvement.
- *Managed lanes are a higher priority for improvement than general purpose lanes.* Where new capacity is to be provided on the highway system, management of that new capacity through managed lanes (either priced or non-priced) and/or transit advantage will receive priority over unmanaged capacity.
- *There are some areas where traditional capacity will not be added; this does not preclude management, operational and pricing solutions.* Demand and system management strategies may be considered for sections of the highway system even without a capacity addition.
- *Needed segments of general purpose lanes may be converted to managed lanes*. For the purpose of management continuity and system efficiency, some situations may require the conversion of general purpose capacity into managed capacity.
- *Highway improvements should enhance and support transit use where existing or planned express transit service exists.* The provision of transit advantage may include the conversion of right-side bus shoulder to left-side managed lanes.
- *Flexible design may be needed to accommodate an improvement or project within the existing right-of-way. Overall safety must be maintained or improved.* The need for flexible design is not a fatal flaw; rather, the burden is upon the project development to indicate safety has not been degraded as a result of the project.
- *Complete the six-lane beltway and unfinished connections to utilize existing and planned investments*. Although the region has a long-standing policy of a six-lane continuous beltway, segments of the beltway may be managed capacity.
- *Do not add inbound capacity outside the beltway that cannot be accommodated by projects or operational changes/strategies on, or within, the beltway*. This principle sets out to avoid demand / capacity imbalance, however existing imbalances may be alleviated by providing transit advantage and outbound capacity.
- *Manage access to Interregional Corridors (IRC's) or other Principal Arterials*. Signalized intersections may be modified or removed, and, access points may be reduced to improve efficiency.
- *Asymmetrical improvements may be considered*. The region may consider capacity expansion to facilities serving outbound throughput, when appropriate.

THE PERFORMANCE MEASURES

From the *Guiding Principles* document, the initial performance measures were derived for eventual use in the screening process. Whereas certain principles lend themselves to screening, prioritization, or scenario selection, certain guiding principles also inform the selection of performance measures. In turn, these performance measures can be detailed into measures of effectiveness.

The selection of performance measures is first dependent upon the overarching purpose of the MHSIS:

- Guide overall mobility decisions by giving direction to fully utilize all highway and modal investments, in a coordinated manner.
- Define the most cost-effective techniques and projects to optimize highway system performance for all users.

From this purpose, overarching goals are clarified for the selection of an MHSIS alternative:

- Develop a future transportation investment strategy that optimizes the investments already made in the region through the use of targeted capacity expansion coupled with multimodal system and demand management strategies. The intent is to better utilize lane capacity, paved shoulders, and right-of-way.
- Identify investment alternatives to improve metropolitan highway system performance and preserve mobility

Finally, specific guiding principles as identified above are used to inform the selected performance measures:

- Utilize the most cost effective operational, management and pricing techniques to optimize system performance. Management strategies, including pricing, High Occupancy Toll (HOT) lanes, High Occupancy Vehicle (HOV) lanes, Intelligent Transportation Systems (ITS), and ramp metering will be used to their fullest extent to improve mobility and relieve congestion before adding new capacity
- Managed and priced lanes are a higher priority for improvement than general purpose lanes. Capacity/mobility projects that contain an element of management or pricing will receive priority in selection. Projects that include transit or transit advantages (e.g.. bus only shoulders) will receive priority in selection

OBJECTIVE #1: INCREASE THE PEOPLE-MOVING CAPACITY OF THE METROPOLITAN HIGHWAY SYSTEM

PERFORMANCE MEASURE CATEGORY: PERSON THROUGHPUT

Person throughput is an important measure of mobility and congestion reduction. Person throughput refers to the number of persons traversing the corridor on both transit and in private vehicles. Increases in the number of persons using a corridor would imply that the operations and management strategies evaluated were effective in serving more persons who are not serviced in the corridor because of the congestion that is present in a no-build context. The identified measures of effectiveness for person throughput are:

- Person Miles Traveled (PMT) by facility and/or lane type
- Vehicle Miles Traveled (VMT) by facility and/or lane type

The identified mechanism for assessing person throughput performance will be the calculated outcomes from the travel demand model for PMT and VMT.

PERFORMANCE MEASURE CATEGORY: TRANSIT MODE SPLIT

A desired outcome of the MHSIS is to increase the use of transit relative to the private auto, leading to a mode shift to transit. Mode shift may result from potential users being attracted to transit, or from increased transit use among occasional users. Thus, the central transit evaluation issue is the identification and measurement of mode shift. In theory, a mode shift to transit should then facilitate higher transit ridership, reduced levels of traffic congestion, more efficient use of existing road capacity, net reduction in greenhouse gas emissions and fuel consumption. and potentially higher levels of person throughput. The identified measures of effectiveness for transit mode shift are:

- Change in treatment corridor mode share
- Change in regional mode share

The identified mechanism for assessing transit mode share performance will be the calculated outcomes from the travel demand model for capacity improvements and from the FHWA Intelligent Transportation Systems Deployment Analysis System (IDAS) model for active traffic management / ITS improvements.

Objective #2: Manage and optimize, to the greatest extent possible, the existing system

Performance Measure Category: Facility Performance

Facility performance partially represents the spatial extent of congestion relative to person trips. For example, the ratio of PMT to VMT provides a measure of trip distribution. Coupled with the percentage of freeway lane miles at degraded levels of service, provides an evaluation of the facility's attraction of users and distribution to competitive alternatives (both modal and route alternatives). With managed lanes comprising a significant investment, average speeds will be delineated to the extent possible by lane type. The identified measures of effectiveness for facility performance are:

- Ratio of PMT / VMT
- Lane miles by volume / capacity exceeding 0.95
- Average speed by facility / lane type

The identified mechanism for assessing facility performance will be the calculated outcomes from the travel demand model for the first two measures. Average speed will be assessed using the travel demand model for traditional improvements and IDAS for active traffic management.

Objective #3: Accommodate future demand within the metropolitan highway system

Performance Measure Category: Peak Period Vehicle Traffic Volumes

Related to the facility performance measure is the total vehicular demand for metropolitan highway capacity. Recognizing the metropolitan highway system provides abundant capacity and only suffers a shortage in the peak periods, this measure identifies the success of alternatives in shifting demand from the peak period. The identified measures of effectiveness for peak period vehicle traffic volumes are:

- Change from baseline in peak hour volumes
- Change in peak period VMT

The identified mechanism for assessing peak period traffic performance will be the calculated outcomes from the travel demand model.

Performance Measure Category: Temporal Extent of Congestion

The temporal extent of congestion refers to how many hours in the day the corridor is operating under congested conditions. As freeway corridors have varying levels of operations and management strategies deployed across treatment sections, this will affect the percentage of VMT experiencing congestion on the metropolitan system. The intent of the evaluation will be to identify the level of success the strategies have upon treatment corridors to this objective. The identified measures of effectiveness for temporal extent of congestion are:

- Number of hours per day facilities are operating with congestion
- Percent change in number of freeway links operating with congestion
- Percent change in non-freeway corridors operating with congestion
- Percent change in VMT during congested conditions
- Percent change in VHT during congested conditions

The identified mechanism for assessing temporal extent of congestion will be the calculated outcomes from the travel demand model.

Objective #4: Increase trip reliability

Performance Measure Category: Travel Time Reliability

Travel time reliability is a key metric for operational and management strategies, yet it remains an elusive metric for estimation and quantification. In order to represent travel time reliability, the MHSIS will use the travel time index as a means of assessing the collective effectiveness of the strategies at reducing congestion between treatment corridors. The travel time index is the ratio of the average peak period travel time as compared to a free-flow travel time. The free-flow travel time for each road section is the 15th percentile travel time during traditional off-peak times (i.e., weekdays between 9 am and 4 pm, between 7 pm and 10 pm; and weekends between 6 am and 10 pm). For example, a value of 1.20 means that average peak period travel times are 20% longer than free flow travel times. Coupled with a calculation of variability, this provides an approximation of reliability. The identified measures of effectiveness for travel time reliability are:

- Variability of trip travel time by facility / lane type
- Change in travel time index (total travel time compared to a free-flow travel time) of travelers

The identified mechanism for assessing travel time reliability will be calculated as follows:

- Variability will be calculated by the change in the percent of lane miles with a volume / capacity ratio in excess of 0.95 for traditional improvements by facility type (data from demand model), and, the IDAS model for ITS/ATM treatments
- The travel time index will be calculated from travel demand model data as the total vehicle hours traveled (VHT) as a ratio of free flow system VHT.

Objective #5: Reduce travel time

Performance Measure Category: Travel Time Savings

Travel time is strongly influenced by the speed that the vehicle is able to travel, as well as any delays experienced due to bottlenecks or other queues caused by congestion. Generally, travel times are measured for specific points on a section of roadway and can be collected separately for different types of facilities (e.g., general purpose lanes versus managed lanes, freeway versus arterial). The MHSIS will evaluate the travel time savings by examining changes in travel times before (no-build) and after (treatment) the strategies have been applied to treatment corridors. The identified measures of effectiveness for travel time savings are:

- Corridor-based travel time by facility / lane type, normalized by traveler
- Percent changes in travel time by treatment corridor
- Differentiation of travel time by mode

The identified mechanism for assessing travel time savings will be the calculated outcomes from the travel demand model for capacity improvements and from the IDAS model for active traffic management / ITS improvements.

Combination of Measures

The following table illustrates the combined measures as identified above.

OBJECTIVES	PERFORMANCE CATEGORIES	MEASURES OF EFFECTIVENESS
Increase the people-moving capacity of the metropolitan highway system	Person Throughput	Person Miles Traveled by facility / lane type
		Vehicle Miles Traveled by facility / lane type
	Transit Mode Split	Change in treatment corridor mode share
		Change in regional mode share
Manage and optimize, to the greatest extent possible, the existing system	Facility Performance	Ratio of PMT / VMT (mode distribution)
		Lane miles at volume / capacity > 0.95
		Average speed by facility / lane type
Accommodate future demand within the metropolitan highway system.	Peak Period Vehicle Traffic Volumes	Change from baseline in peak hour volumes
		Change in peak period VMT
	Temporal Extent of Congestion	Hours per day operating with congestion
		Change in freeway links operating with congestion

		Change in non-freeway corridors operating with congestion
		Change in VMT during congested conditions
		Change in VHT during congested conditions
Increase trip reliability	Travel Time Reliability	Variability of travel time by facility / lane type
		Change in travel time index (total travel time compared to a free-flow travel time) of travelers
Reduce travel time	Travel Time Savings	Corridor-based travel time by facility / lane type
		Change in travel time by treatment corridor
		Differentiation of travel time by mode