Addendum to Traffic Analysis Toolbox Volume VII: Predicting Performance with Traffic Analysis Tools

Reliability Analysis Guidance Addendum

September 2023

U.S. Department of Transportation
Federal Highway Administration

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This document reflects up-to-date guidance on incorporating travel time reliability in the Traffic Analysis Toolbox Volume VII. It provides insights into the common pitfalls and challenges associated with use of traffic analysis tools for predicting future performance of a transportation facility. It provides five in-depth case studies that demonstrate common ways to ensure appropriate results when using a microsimulation tool and also includes "how to" material that allows users to address common challenges associated with microsimulation analysis.</td></tr>
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SI* (MODERN METRIC) CONVERSION FACTORS				
APPROXIMATE CONVERSIONS TO SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1,000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2,000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa
APPROXIMATE CONVERSIONS FROM SI UNITS				
Symbol	**When You Know**	**Multiply By**	**To Find**	**Symbol**
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2,000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	2.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380. (Revised March 2003)

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1. PURPOSE

This document is an addendum to the *Traffic Analysis Toolbox Volume VII: Predicting Performance with Traffic Analysis Tools* (Federal Highway Administration Report No. FHWA-HOP-08-055[1]) and reflects up-to-date guidance on incorporating travel time reliability (TTR) in the Traffic Analysis Toolbox. The addendum consists of:

- Updates to the existing Toolbox volume text
- Additional content to be appended to the Toolbox volume

[1]Luttrell, T., W. Sampson, D. Ismart, and D. Matherly. 2008. *Predicting Performance with Traffic Analysis Tools – Final Report*. Report FHWA-HOP-08-055. Washington, DC: Federal Highway Administration. https://ops.fhwa.dot.gov/publications/fhwahop08055/index.htm, last accessed January 11, 2023.

CHAPTER 2. UPDATES TO THE EXISTING TOOLBOX VOLUME TEXT

INTRODUCTION

On Page 3: With reference to the case study on the traffic signal network in Chicago, IL, the reader should note that level of service (LOS) typically does not account for TTR. A more robust analysis should include multiple performance measures related to TTR (e.g., buffer index (BI), travel time index (TTI), planning time index (PTI), and probability of on-time arrival) and accompanying visualizations (e.g., scatterplots, histograms, and probability density functions).

CASE STUDY 1: INTERSTATE 494 (I–494) AND TRUNK HIGHWAY 7 IN MINNEAPOLIS, MN

On Page 5: With reference to the data collection approach for this case study, the reader should note that a robust analysis should include multiple performance measures and visualizations related to TTR. Moreover, a TTR analysis should not exclude bad weather days or traffic incident days.

PRACTICAL GUIDANCE ON THE APPLICATION OF TRAFFIC SIMULATION AND ANALYSIS TOOLS FOR TRANSPORTATION INVESTMENT DECISIONS

On Page 43: With reference to the suggestion "J. Different Definitions of Level of Service (Or I Can't Define the LOS F But I Know It When I See It)," the reader should note that LOS typically does not account for TTR. A more robust analysis should include multiple performance measures related to TTR (e.g., BI, TTI, PTI, and probability of on-time arrival).

CHAPTER 3. ADDITIONAL CONTENT TO BE APPENDED TO THE TOOLBOX VOLUME

INADEQUATE CONSIDERATION OF TRAVEL TIME RELIABILITY

There are fundamental differences in how traffic operations and quality of service are evaluated according to TTR versus how they would be evaluated according to simple averages. These fundamental differences may change important and bottom-line traffic analysis conclusions, such as site congestion rankings and control strategy rankings. Many natural variations occur throughout a typical year. Traditional methods account for such variation by identifying a representative "analysis hour." The chosen analysis hour (e.g., 30th highest hour, meaning only 29 other hours throughout the year experienced a higher demand volume) is intended to balance a transportation agency's desire to provide adequate operations during the large majority of hours of the year with its need to use limited resources as efficiently as possible.[2] However, the 30th highest hour demand level does not provide complete information on how much demand variability occurs throughout the year and throughout the day. It also does not account for other sources of natural variation (e.g., weather and incidents) or for directional (e.g., inbound versus outbound) variability.

A modern traffic analysis can be considered robust if it produces multiple performance measures related to TTR (e.g., BI, TTI, PTI, and probability of on-time arrival) and accompanying visualizations (e.g., scatterplots, histograms, and probability density functions). By contrast, peak-hour analyses based on simple averages may produce optimistic outcomes rarely observed in the field. A traffic analyst should seek to observe and understand the full range of traffic conditions that occur throughout the day, week, and year. There are a number of options for achieving this:

- A rigorous and comprehensive approach is to develop model scenarios having appropriate combinations of traffic volume demand, weather, incident, and special events. Scenario-based reliability analysis procedures for traffic simulation and *Highway Capacity Manual* methods are described in the Second Strategic Highway Research Program 2 (SHRP 2) L04[3] and L08[4] reports, respectively, and are implemented by some software packages (Mahmassani et al. 2014; Zegeer et al. 2014). Calibration of simulation models would be accomplished by the cluster analysis methods described in TAT Volume III[5] (Wunderlich, Vasudevan, and Wang 2019).

- A less rigorous approach would be to apply the scenario-based procedures manually, with fewer scenarios and customized adjustment factors. In this approach, the analyst would

[2] Dowling, R., P. Ryus, B. Schoeder, M. Kyte, F. T. Creasey, N. Rouphail, A. Hajbabaie, and D. Rhoades. *Planning and Preliminary Engineering Applications Guide to the Highway Capacity Manual*. NCHRP Report 825. Washington, DC: National Academies of Sciences, Engineering, and Medicine.
[3] https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2193.
[4] https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2197.
[5] Wunderlich, K., M. Vasudevan, and P. Wang. 2019. *TAT Volume III: Guidelines for Applying Traffic Microsimulation Modeling Software: 2019 Update to the 2004 Version*. Report No. FHWA-HOP-18-036. Washington, DC: Federal Highway Administration. https://ops.fhwa.dot.gov/publications/fhwahop18036/index.htm, last accessed January 11, 2023.

use judgment to review their chosen number of scenarios. Again, their goal would be to develop a confident opinion about the full range of traffic conditions that occur throughout the day, week, and year.

- Finally, some planning agencies have conducted quick order-of-magnitude assessments using the data-poor reliability prediction equations from SHRP 2 L03[6] (Margiotta et al. 2013). This is effectively a sketch-planning approach to reliability analysis. Case studies that illustrate the use of these methods are provided within SHRP 2 L05[7] (Hranac et al. 2014).

CASE STUDY: INTERSTATE 35W NORTH CORRIDOR PRELIMINARY DESIGN PROJECT

Project Description

This case study details the methodologies and results of the TTR analysis conducted for the I-35W North Corridor Preliminary Design Project. The project involved evaluating capacity expansion on a major radial freeway corridor connecting greater Minnesota and the growing north suburban area to downtown Minneapolis. The study team developed reliability results for existing (year 2014) conditions, year 2040 no-build, and year 2040 build alternatives, which include the addition of one general-purpose (GP) lane, a high-occupancy vehicle (HOV) lane, and a high-occupancy/toll lane (MnPASS lane) in each direction. The purpose of this study is to demonstrate how robust reliability measures can be developed for several forecast year scenarios to assist stakeholders in project-level decisionmaking. The case study will lay out the methods and procedures used to complete the reliability analysis and the results of the evaluation. These alternatives will then be evaluated with a screening process to compare their effectiveness.

Reliability is an emerging area of transportation evaluation that considers the variability in travel times that occur due to weather, crashes, and other nonrecurring conditions. Understanding these effects for managed lanes is particularly important as these facilities are specially intended to provide free-flow travel for transit, carpools, and single-occupant vehicles willing to pay a congestion-sensitive toll. Communicating these results to stakeholders is critical in demonstrating the long-term value of this type of investment.

Data Sources

Analysis of the I–35W corridor was broken into eight segments, four in each direction. Data for the analysis came from a variety of sources. Travel time and volume data from the Minnesota Department of Transportation's (MnDOT's) loop detector system were extracted using both MnDOT's Data Extract tool and the Traffic Information and Condition Analysis System (TICAS). Weather and precipitation data were obtained from the National Oceanic and

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[6] National Academies of Sciences, Engineering, and Medicine (NASEM). 2022. "SHRP 2 L03: Analytic Procedures for Determining the Impacts of Reliability Mitigation Strategies" (web page). https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2179, last accessed January 11, 2023.
[7] NASEM. 2022. "SHRP 2 L05: Incorporating Reliability Performance Measures into the Transportation Planning and Programming Processes" (web page). https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=2194, last accessed January 11, 2023.

Atmospheric Administration, and Minnesota Department of Public Safety crash records were accessed through the Minnesota Crash Mapping Analysis Tool.

Methodologies

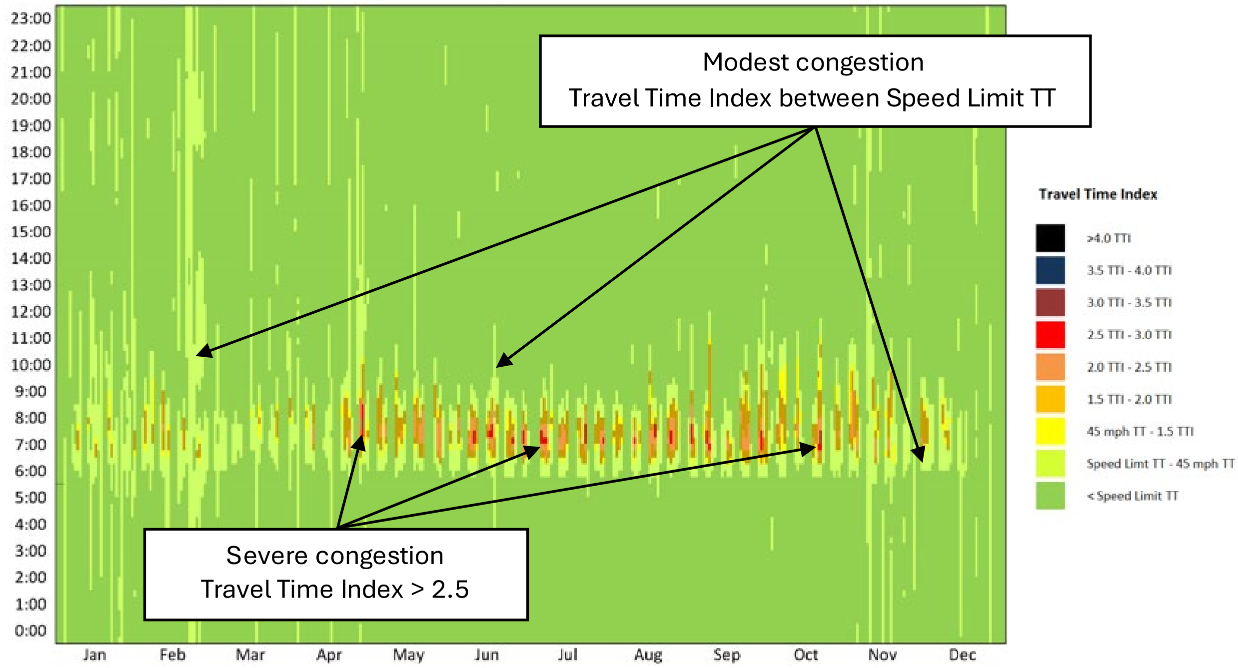
To fully understand the TTR for the existing condition, the study team collected 1 year of travel time data along the project corridor for the calendar year 2014. The team calculated reliability indices such as PTI, TTI, and BI. In addition, the team obtained weather and crash data and integrated them with travel time data for the full year of 2014 to isolate the effects of these factors.

To characterize the relationship between the general-purpose (GP) and MnPASS lanes and to project travel time savings for the I–35W North MnPASS project, 1 year of travel time data along existing GP and MnPASS lanes on the nearby facilities of I–394 and I–35W South were collected and analyzed. In terms of future year travel demands, traffic volume and transit ridership forecasts were prepared using the Twin Cities Regional Travel Demand Model (RTDM) for both existing and year 2040 alternatives.

The reliability analysis was ultimately summarized using a variety of outputs to illustrate the variability of travel times and throughput under the alternatives considered.

Surface Plots (Existing and Future Projection)

A surface plot is the visual representation of travel times every 15 minutes (min) for 1 year relative to free-flow travel time. The plot for existing conditions (Figure 1) used the loop detector speed data downloaded from TICAS and converted it to TTI values, which is the ratio of observed travel time to the free-flow travel time.



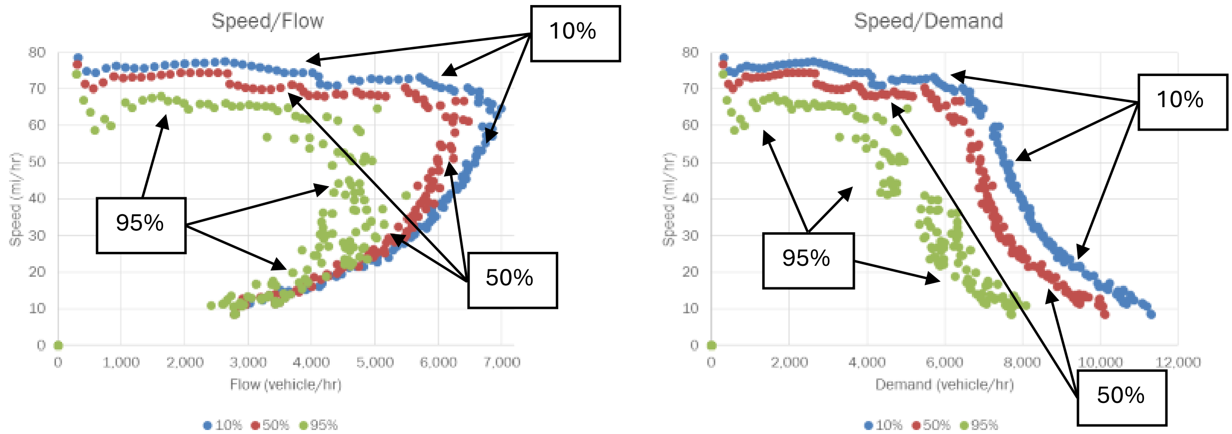
Source: Minnesota Department of Transportation

TTI = travel time index; TT = travel time.

Figure 1. Plot. Interstate 35W southbound travel time surface plot—2014 conditions.

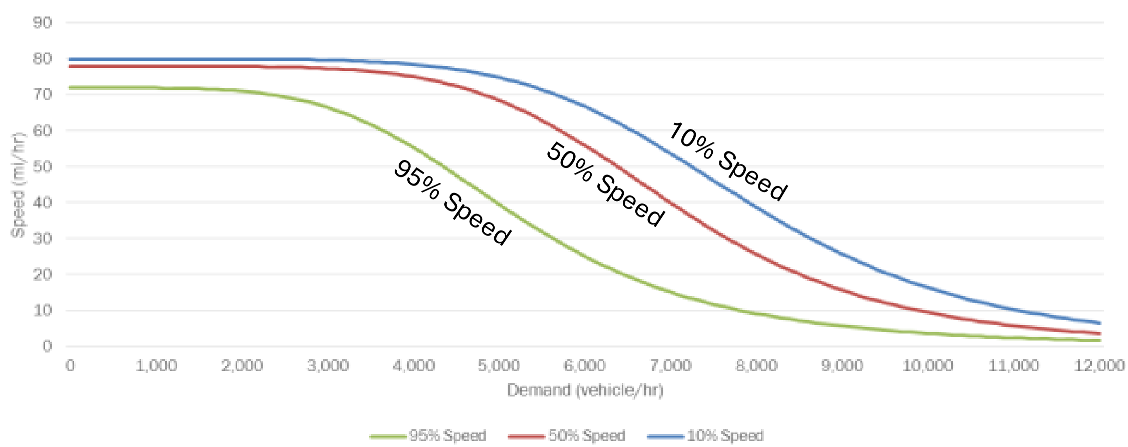
Estimating Demand-Speed Curves

According to the existing speed-flow relationships (Figure 2, left), analysts can identify segment capacities for different percentiles of speed. Traffic under the critical speed (speed at capacity) was assumed to be the unserved demand (Figure 2, right). Based on the scatterplots, the study team estimated demand-speed curves (Figure 3) and used these to project future demand-speed relationships.



Source: Minnesota Department of Transportation

Figure 2. Graph. Flow-speed versus demand-speed curves (Interstate 35W southbound example from US 10 to Interstate 694).



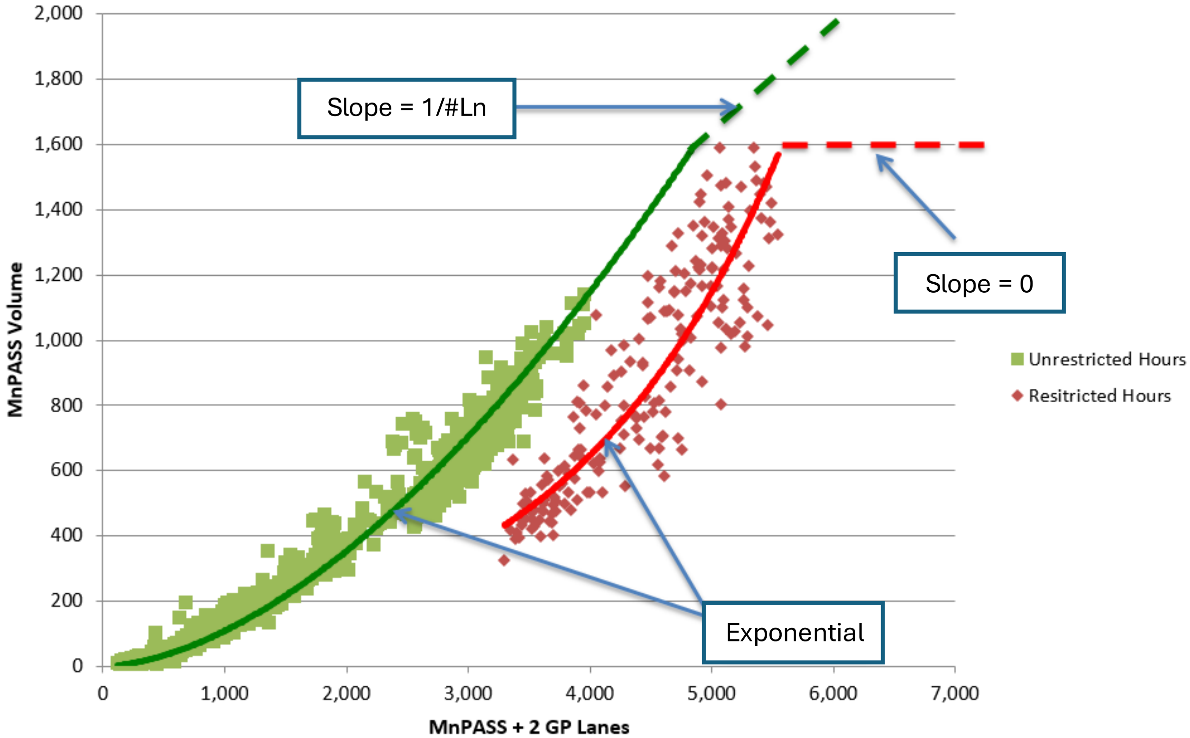
Source: Minnesota Department of Transportation

Figure 3. Graph. Estimated demand-speed curves (Interstate 35W southbound example from US 10 to Interstate 694).

The 2040 alternatives applied the same demand distributions for both recurring and nonrecurring conditions and scaled the volume profiles based on the annual average daily traffic forecasts that are RTDM generated. Using the speed curves estimated based on the speed-demand relationship, the study team evaluated each 15-min volume to assign a travel time. The team then carried unserved demands forward to the next time interval.

Relationship Between MnPASS and General-Purpose Lanes

To project the reliability conditions among MnPASS and GP lanes in 2040, the existing volume data of the road segments having similar MnPASS facilities were collected and analyzed. The example in Figure 4 shows the existing MnPASS and GP relationship on northbound I–35W at the Minnesota River. The scatterplot in Figure 4 reveals the relationship between the MnPASS and GP volumes during unrestricted and restricted hours. Exponential equations were found to provide the best fit for volumes under capacity and were applied for the future MnPASS build alternative.

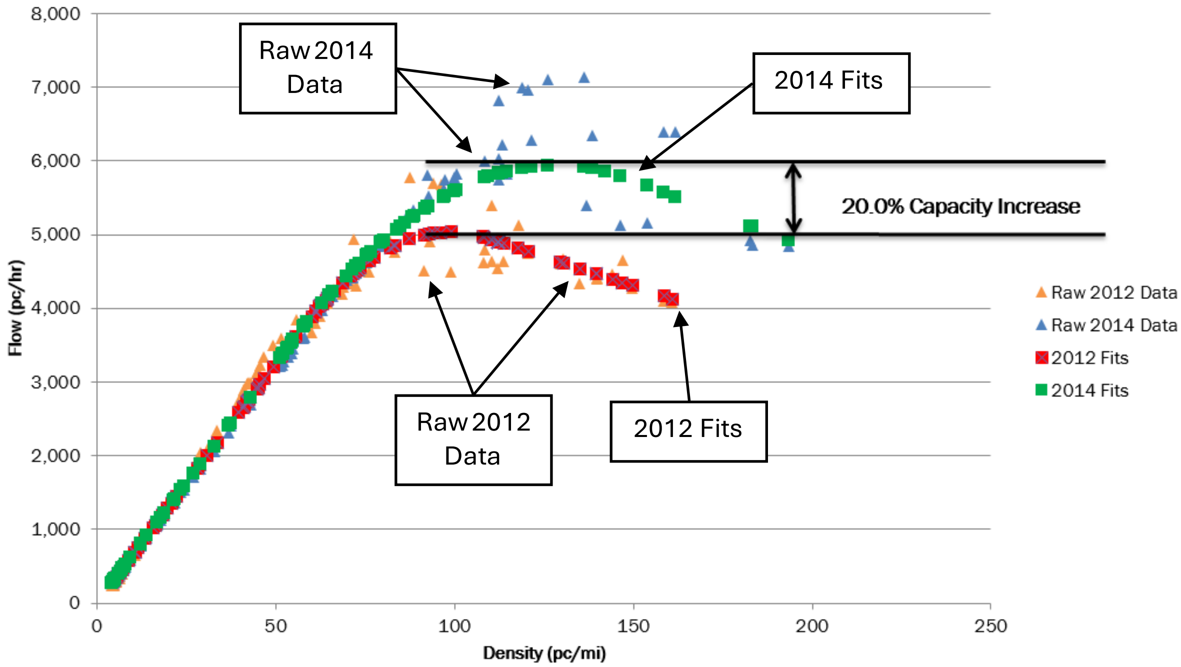


Source: Minnesota Department of Transportation

Figure 4. Graph. Existing MnPASS and general-purpose relationship example.

Additional Capacity of Adding General-Purpose Lanes

For the 2040 GP lane alternative, the capacity increase is a critical factor to the reliability analysis. A few completed projects that added additional lanes were used as guidance to establish the additional capacity impacts. Figure 5 shows an example of a recent existing GP lane addition on westbound I–494 from I–35W to France Avenue. Flow and density data were collected before and after the lane expansion. The results indicate a 20-percent capacity increase after adding one additional GP lane to the three existing GP lanes.



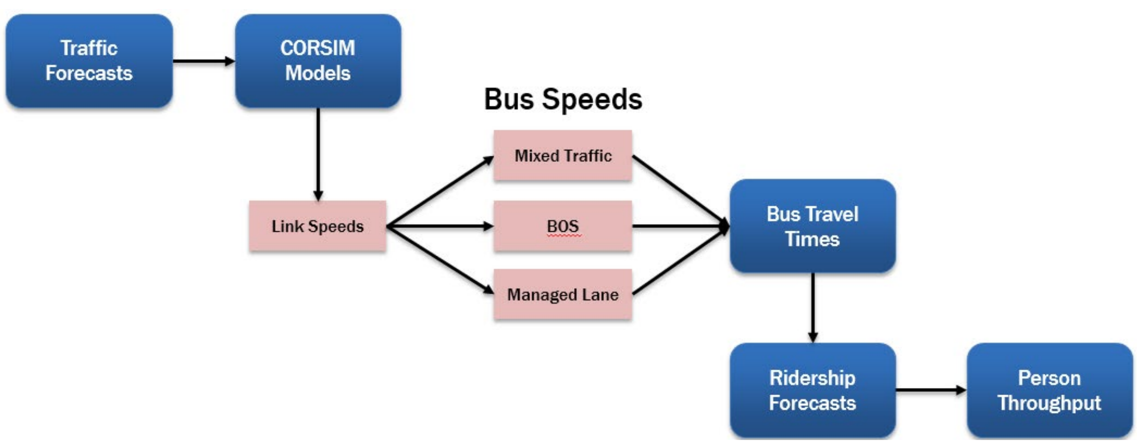
Source: Minnesota Department of Transportation

pc = passenger cars.

Figure 5. Graph. Capacity increase with general-purpose lane addition.

Transit Ridership Forecasts

Transit ridership was a key factor in this reliability evaluation, as the proposed MnPASS lanes provide travel time and person throughput benefits for express buses. Figure 6 shows the flow chart of the ridership forecasting. Bus travel times were obtained from CORSIM modeling, and ridership was forecasted using RTDM. With bus travel time and ridership, travel time savings and person throughput can be calculated for different alternatives in the year of 2040.

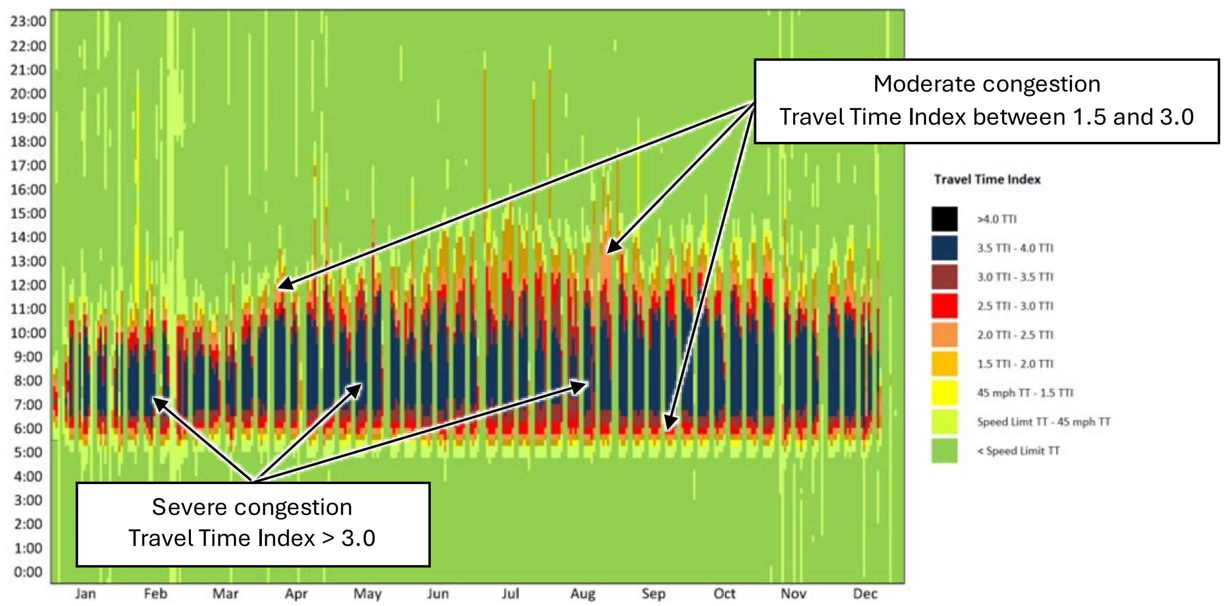


Source: Minnesota Department of Transportation

CORSIM = corridor simulation; BOS = bus on shoulder.

Figure 6. Flowchart. Transit forecast.

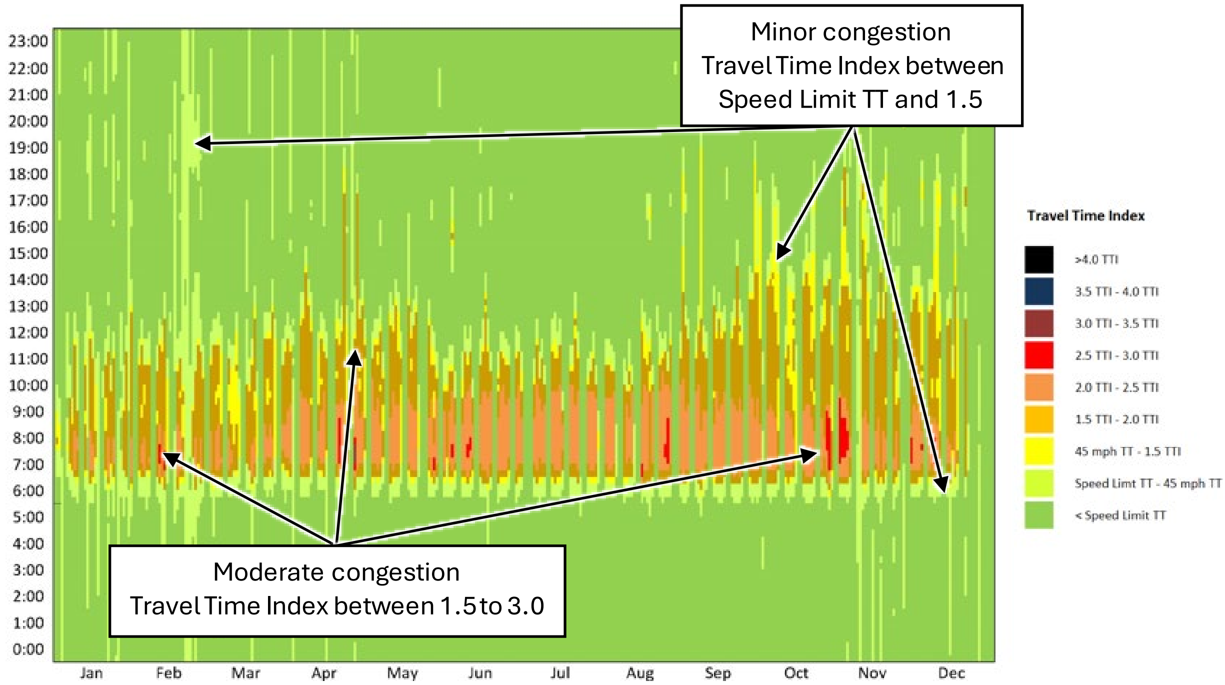
With all the assumptions summarized above, the travel times for the 2040 no-build and build alternatives were projected. Figure 7, Figure 8, Figure 9, and Figure 10 show the travel time surface plots for 2040 no-build, GP, MnPASS, and HOV alternatives, respectively. Figure 11 shows the congestion conditions for MnPASS/HOV lanes. Although the GP lanes under the MnPASS and HOV alternatives are more congested than the GP alternative, the MnPASS and HOV alternatives offer users a congestion-free option by using these managed lanes.



Source: Minnesota Department of Transportation

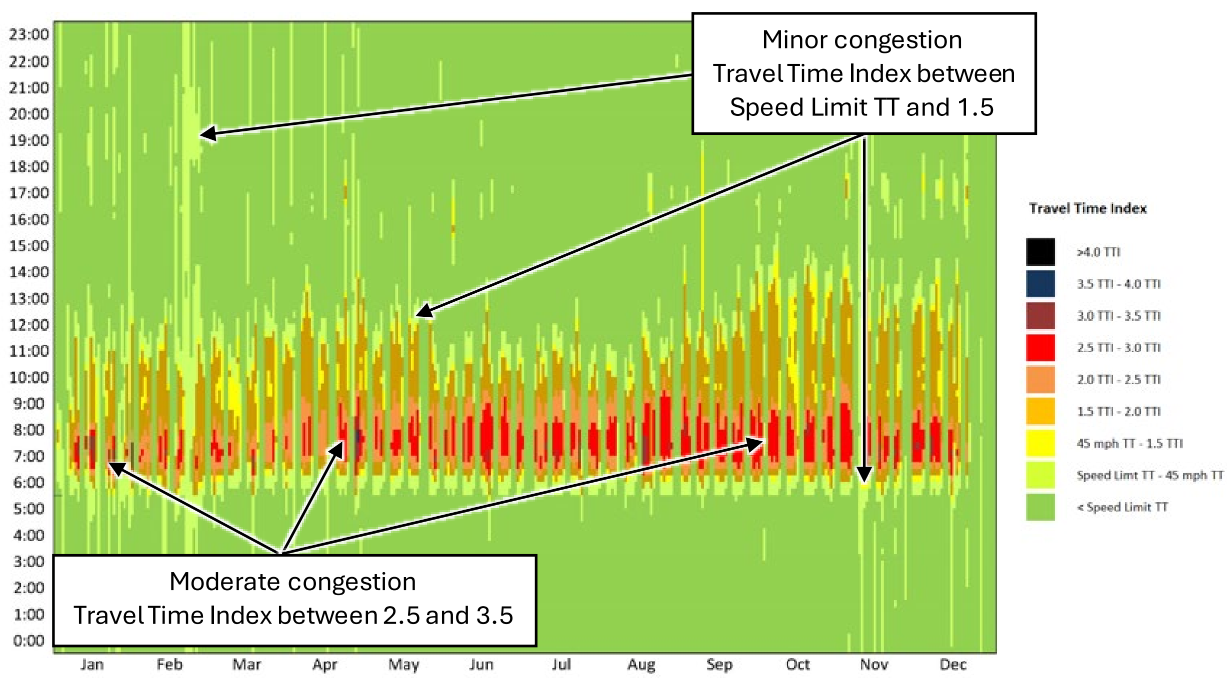
TTI = travel time index; TT = travel time.

Figure 7. Graph. Interstate 35W southbound travel time surface plot—2040 no-build alternative.



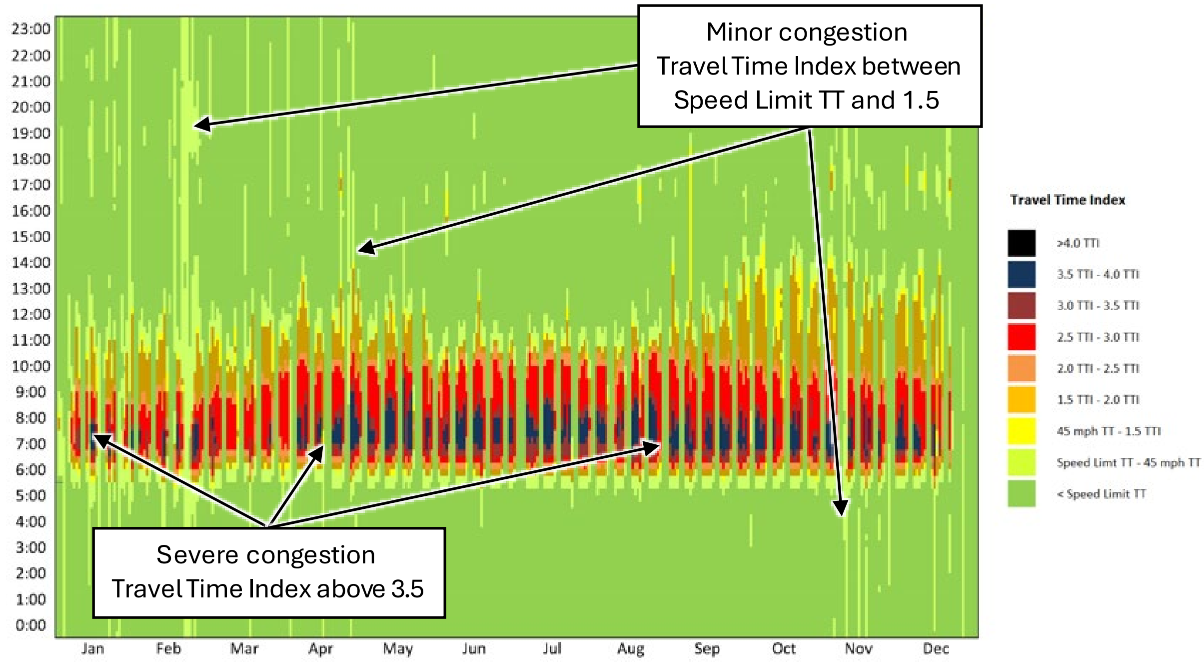
Source: Minnesota Department of Transportation

Figure 8. Graph. Interstate 35W southbound travel time surface plot—2040 general-purpose alternative.



Source: Minnesota Department of Transportation

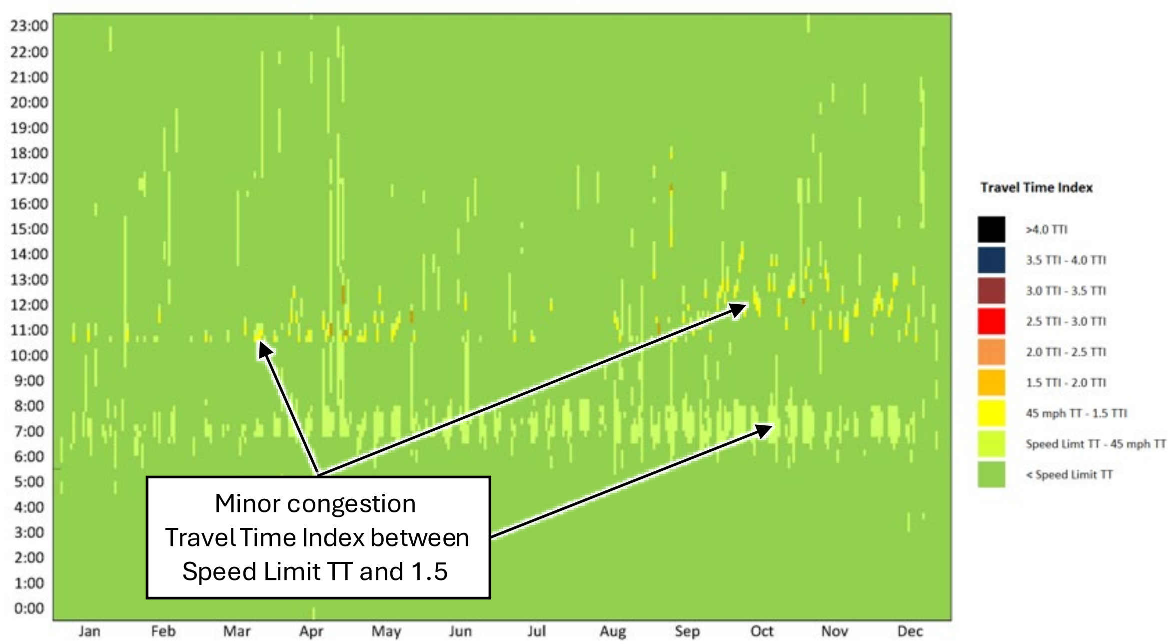
Figure 9. Graph. Interstate 35W southbound travel time surface plot—2040 MnPASS alternative (general-purpose lanes).



Source: Minnesota Department of Transportation

TTI = travel time index; TT = travel time.

Figure 10. Graph. Interstate 35W southbound travel time surface plot—2040 high-occupancy vehicle alternative (general-purpose lanes).



Source: Minnesota Department of Transportation

TTI = travel time index; TT = travel time.

Figure 11. Graph. Interstate 35W southbound travel time surface plot—2040 MnPASS/high-occupancy vehicle lanes.

Travel Time Thermometers

The travel time thermometers provide a representation of the typical variability in travel times experienced by a user along the corridor. There are 20 increments for each thermometer, and each represents the percentile of the travel time during a specific time range. The percentile ranges from 2.5th to 97.5th, with a 5-percent increment. These increments were selected to represent 20 typical perk period commutes that may occur within 1 month (5 days/week times 4 weeks).

Table 1 shows the comparison of thermometers for southbound I–35W during the a.m. peak hours. The values are shown in minutes, and the colors show the TTI ranges consistent with the surface plots (as shown in Table 3). By comparing the congestion conditions for GP lanes, the GP alternative offers the best reliability. However, the MnPASS alternative offers a congestion-free condition in the MnPASS lane Table 2.

Table 1. Interstate 35W southbound travel time thermometer for weekday a.m. peak hours across different build conditions.

Rank	Travel Time in Minutes				
	Existing	No Build	2040 GP	2040 MnPASS	2040 HOV
1	14.6	14.7	14.7	14.7	14.7
2	14.9	18.7	15.4	15.9	16.5
3	15.1	28.3	16.0	16.7	18.5
4	15.4	33.6	16.6	17.8	21.0
5	15.6	39.5	17.4	19.3	23.9
6	15.9	43.6	18.6	21.3	27.3
7	16.2	47.8	20.3	23.5	32.2
8	16.5	50.2	22.4	25.6	36.6
9	16.8	52.3	24.2	27.5	40.7
10	17.2	55.0	25.2	29.6	43.0
11	17.7	57.2	26.9	32.2	43.5
12	18.4	58.5	29.3	34.6	44.4
13	19.3	58.8	32.3	36.6	46.2
14	20.3	58.8	34.4	38.2	48.3
15	21.6	58.8	35.3	39.7	50.8
16	23.5	58.8	35.5	41.4	54.1
17	25.3	58.8	35.7	43.0	56.7
18	27.6	58.8	35.9	43.9	58.6
19	31.6	58.8	36.4	45.0	58.8
20	37.9	58.8	40.5	48.3	58.8

Source: Minnesota Department of Transportation

GP = general purpose; HOV = high occupancy vehicle.

Table 2. Interstate 35W southbound travel time thermometer for weekday a.m. peak hours across 2040 conditions.

Rank	Travel Time in Minutes		
	2040 GP	2040 MnPASS (GP Lanes)	2040 MnPASS (MnPASS Lane)
1	14.7	14.7	14.5
2	15.4	15.9	15.0
3	16.0	16.7	15.3
4	16.6	17.8	15.5
5	17.4	19.3	15.6
6	18.6	21.3	15.7
7	20.3	23.5	15.7
8	22.4	25.6	15.8
9	24.2	27.5	15.9
10	25.2	29.6	15.9
11	26.9	32.2	16.0
12	29.3	34.6	16.1
13	32.3	36.6	16.2
14	34.4	38.2	16.2
15	35.3	39.7	16.2
16	35.5	41.4	16.3
17	35.7	43.0	16.3
18	35.9	43.9	16.4
19	36.4	45.0	16.7
20	40.5	48.3	17.6

Source: Minnesota Department of Transportation

GP = general purpose; HOV = high occupancy vehicle.

Table 3. Correlation between travel time and travel time index for Interstate 35W southbound.

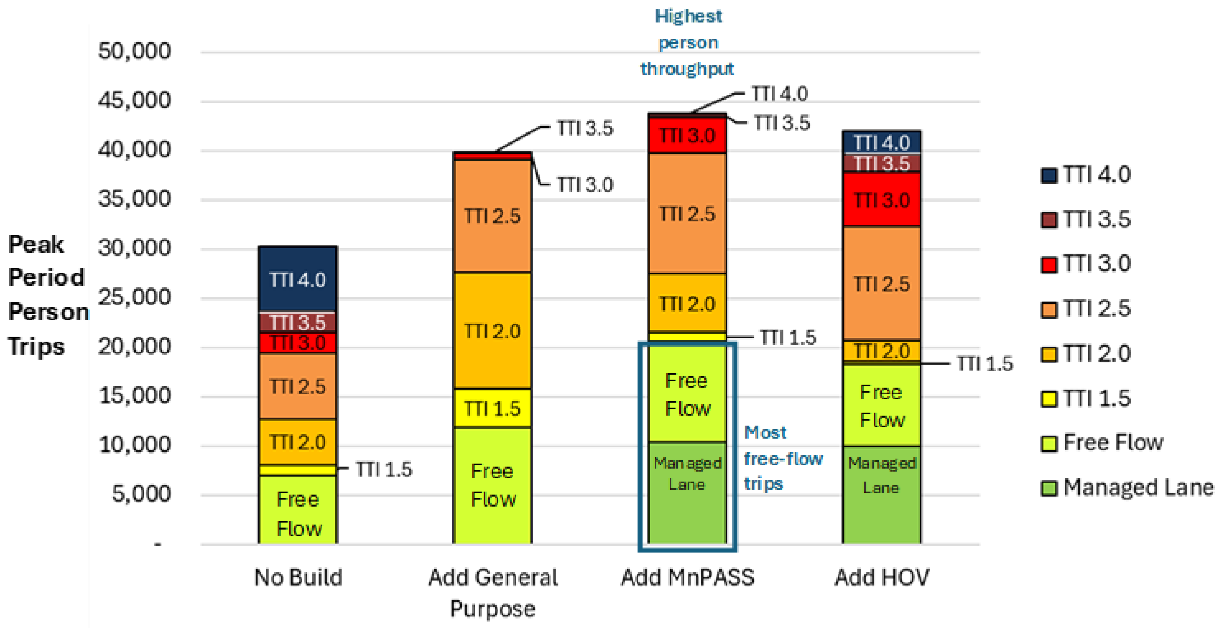
Travel Time Index	Travel Time in Minutes
< Speed Limit Travel Time	< 16.5
< 45 MPH Travel Time	16.5 – 23
45 MPH – 1.5 TTI	23 – 25
1.5 – 2.0 TTI	25 – 33
2.0 – 2.5 TTI	33 – 40
2.5 – 3.0 TTI	40 – 49
3.0 – 3.5 TTI	49 – 57
3.5 – 4.0 TTI	57 – 66
> 4.0 TTI	> 66

Person Throughput Bar Charts

Scaling the thermometers based on person throughput produces stacked bar charts incorporating travel time and throughput data into a single visual figure, showing not only the total person throughput in each alternative but the throughput at different travel time ranges.

The person throughput is calculated with volume and vehicle occupancy. The existing volumes were collected from the loop detectors, and the occupancies were from field data collection. For year 2040 alternatives, RTDM generated the volumes and single-occupancy vehicle/HOV ratios, which were used to interpolate occupancies. In addition, the congestion levels are displayed by distinct colors consistent with the thermometer and the surface plots.

Figure 12 represents the person throughput along I–35W during peak hours and peak directions by TTI level. The stacked bar charts show both the number of users being served under each alternative and their respective travel times. The MnPASS alternative offers a 10-percent increase in total person throughput over the GP alternative. Additionally, the MnPASS alternative provides a 75-percent increase in the number of reliable trips.



Source: Minnesota Department of Transportation

HOV = high-occupancy vehicle; TTI = travel time index.

Figure 12. Graph. Reliability by person throughput—peak hours and peak directions.

Screening Process

The purposes of the screening process are to understand traffic performance under different alternatives and to select the best build alternative for year 2040. The screening criteria include travel time savings, transit advantages, person throughput, LOS, and benefit-cost analysis. Most criteria rely on elements of the TTR analysis results.

Travel Time Savings

The criteria for travel time savings are set as percent delay reduction between the no-build alternative and each of the build alternatives (see Table 4). By measuring the person-hours of travel (PHT) and person delay, the percent delay reduction is highest (69 percent) for the MnPASS alternative compared to the no-build alternative.

Table 4. Travel time savings.

Criteria	No-Build	Free-Flow	Add General Purpose	Add MnPASS	Add HOV
Travel Time (PHT)	11.9M	5.5M	PHT: 8.1M (-3.8M) Delay: 2.6M Percent Decrease: 59 percent	7.5M (-4.4M) Delay: 2.0M Percent Decrease: 69%	8.1M (-3.8M) Delay: 2.6M Percent Decrease: 59%

HOV = high-occupancy vehicle.

Transit Advantages

The criterion for transit advantages is set as transit time savings during peak hours versus the no-build alternative (see Table 5). In addition, the ridership is considered. The MnPASS and HOV alternatives have the lowest travel time and highest ridership.

Table 5. Transit advantages.

Criteria	No-Build	Free-Flow	Add General Purpose	Add MnPASS	Add HOV
Transit Advantages—Transit Travel Time SB a.m. + NB p.m. Peak Hour total round trip (min)	59	40	53	45	45
Transit Ridership (Routes 250, 252, 288)	4,300	4,600	4,200	4,600	4,600

HOV = high-occupancy vehicle; NB = northbound; SB = southbound.

Person Throughput

The criterion is set as the weighted person throughput by segment (see Table 6). The MnPASS alternative has the highest person throughput, and it is 40-percent higher than the no-build alternative.

Table 6. Person throughput.

Criteria	No-Build	Free-Flow	Add General Purpose	Add MnPASS	Add HOV
Person Throughput (SB AM + NB PM Peak Hours; weighted by segment length)	13,200	18,300	16,000	18,300	17,300

HOV = high-occupancy vehicle; NB = northbound; SB = southbound.

Level of Service

The criteria are set as percent lane-mile-hours at LOS D or better based on traffic operations modeling completed using CORSIM software (see Table 7). As the results are within a few percentage points for the three build alternatives, this measure is not a meaningful differentiator of performance.

Table 7. Level of service.

Criteria	No-Build	Free-Flow	Add General Purpose	Add MnPASS	Add HOV
LOS (percent of peak period/peak direction at LOS D or better)	54%	100%	60%	56%	57%

LOS = level of service.

Benefit-Cost Analysis

The benefit-cost analysis is a comprehensive analysis considering travel times based on the reliability analysis, person throughput, and incremental construction and maintenance costs for all of the build alternatives (see Table 8). In terms of the benefit-cost analysis ratios, the MnPASS alternative is 8.11 compared to the GP alternative, and the ratio for the HOV alternative is 0.16. This shows that the additional investment to operate the proposed lanes as MnPASS will provide benefits that exceed the cost compared to GP lanes.

Table 8. Benefit-cost analysis.

Criteria	No-Build	Free-Flow	Add General Purpose	Add MnPASS	Add HOV
Benefit-cost analysis	-	-	-	8.11 versus GP	0.16 versus GP

GP = general purpose.

Findings

The MnPASS and HOV alternatives offer users a congestion-free option. In exchange, the GP lanes under the MnPASS and HOV alternatives are slightly more congested than under the GP alternative. This comparison of alternatives can be seen in both the surface plots and thermometers. Unlike the HOV alternative, the MnPASS option provides a congestion-free alternative to single-occupancy vehicles while still providing an advantage to HOVs and transit. The bar charts show both the number of users served under each alternative and their respective travel times. The MnPASS alternative offers a 10-percent increase in total peak period person throughput over the GP alternative. Additionally, the MnPASS alternative provides a 75-percent increase in the number of reliable trips. Through the screening process, the MnPASS alternative maximizes the benefit and provides a more reliable travel facility for future I–35W users.

Extensions and Guidance

This case study displayed the meaningfulness of performing a comprehensive reliability evaluation. Although the traditional peak-hour LOS analysis showed relatively similar performance across build alternatives, significant user benefits were revealed when assessing overall annual travel time, person throughput, and number of reliable trips. Additionally, the analysis showed how robust predictive reliability evaluations are possible through limited modeling effort, using only outputs from a travel demand model along with existing field-measured data.

A similar analysis would require a rich source of existing traffic data, however. The analysis was able to acquire annual travel time and volume data from MnDOT loop detectors to use as a foundation for the predictive analysis. If such data are unavailable, the analyst may need to resort to sketch planning reliability tools developed for data-poor evaluations. On the other hand, if more detail is desired, a more rigorous effort using microsimulation and the input of multiple scenarios that contain variable demand and capacity may be necessary.

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