Bring Back 6th Alternatives Analysis

Model Review - DRAFT

Prepared for Our Streets

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Contents

Executive Summary

I am evaluating Bring Back 6th alternatives for Our Streets using an enhanced version of the Metropolitan Council travel demand model. In this report, I evaluate the existing model. In subsequent work, I will develop the enhanced model and do the alternatives analyses.

Vehicle mobility is a key metric in roadway alternatives analyses. Given the relative lack of congestion in this corridor, the September 2023 Olson Memorial Highway Multimodal Study Purpose and Need Statement ("*P&NS*") prepared by MnDOT lists vehicle mobility only as a secondary need. Even though vehicle mobility is given as a secondary need, it is possible that it will still have a large weight in evaluation because vehicle mobility metrics are ubiquitous in alternatives analyses and can appear to be more objective compared to some of the other metrics that are harder to quantify.

The vehicle mobility metrics are taken from computer models. For the metrics to be credible, it is necessary that the model match metrics for existing traffic conditions. As documented in this report, the current Met Council model does not. Problems in Olson Memorial Highway modeling include:

- large errors in traffic volumes,
- large errors in traffic speeds, and
- modeled speeds being overly sensitive to roadway capacity.

An old adage in computer modeling is: "All models are wrong; some models are useful." Unfortunately, in its current state, the regional model is not useful for evaluating Olson Memorial Highway alternatives.

These types of model issues are present throughout the United States. Increased computer power has led improved modeling in some domains including weather forecasting, but it has not improved the accuracy of transportation forecasting significantly. The focus over the past 20 years has been on activity-based models ("ABMs"), including the Met Council model. It was assumed that simulating the travel patterns of individuals within individual households, including simulating future virtual individuals and households, would improve model accuracy. However, ABMs have not addressed the models' fundamental issues in matching speeds and traffic volumes. In addition, ABMs have hindered progress in these areas because the added complexity makes the models very cumbersome to update or even to apply. The Met Council model is built on household activity survey data from 2010, a full decade before the start of the pandemic that has had lasting impacts on behavior.

The enhanced model will keep the ABM structure but focus on better matching of existing speeds and traffic volumes.

Even with an improved model, it is best to think of the model as one seat at the table in dialog with other types of data and community input. The horizon year for planning major road projects in the region is 2050. Any statement like: "In 2050, Alternative A will result in time savings of 1.37 minutes" should be met with extreme skepticism. No model will ever be that accurate. An improved model will be more useful than the current one, but it will not be able to predict the future in 2050 precisely. There are too many uncertainties about the effects demographic changes, energy prices, climate regulation, telecommuting and distance learning, virtual reality, artificial intelligence, and other changes.

Although it will be incapable of making precise predictions for 2050, the enhanced model will be useful in a general comparison of alternatives. The model also can be used to test whether the general ranking of alternatives is sensitive to key assumptions about the future. How much the model should be weighted relative to other input will depend on how much the model can be improved, but the model should never override other input.

It also is important not to focus too much on the metrics that can be quantified. the P&NS documents that current average speeds in the corridor are considerably higher than the posted speed. Nevertheless, the Olson Memorial Highway Multimodal Study Evaluation Criteria report (January 2024) includes "corridor travel time" as a metric with an assumption greater than a 20% decrease is "good," greater than a 20% increase is "poor," and lesser changes are "fair." The travel time metric is problematic in this corridor because calming traffic will be required to meet the primary walkability and bikeability needs. Therefore, any alternative that meets the primarily needs will likely rate "poor" on corridor travel time. The decision process should focus on the primary purposes and needs, even if the metrics are qualitative rather than quantitative.

1. The Role of Transportation Models in Evaluating Alternatives

1.1. Vehicle Mobility Is Evaluated Using Models

1.1.1. Purpose and Need Statement

Vehicle mobility is a key metric in roadway alternatives analyses. Given the relative lack of congestion in this corridor, the September 2023 Olson Memorial Highway Multimodal Study Purpose and Need Statement ("*P&NS*") prepared by MnDOT lists vehicle mobility only as a secondary need (p.2).

Even though vehicle mobility is given as a secondary need, it is possible that it will still have a large weight in evaluation because vehicle mobility metrics are ubiquitous in alternatives analyses and can appear to be more objective compared to some of the other metrics that are harder to quantify.

The *P&NS* indicates that in a No Build alternative that vehicle mobility will decline between the base year and the 2045 horizon year. *P&NS* Table 20 shows intersection level-of-service ("*LOS")* and is reproduced on the following page. Most of the intersections are shown to function well, but modeled deficiencies jump out at the reader as they are highlighted in red. This red color visually exaggerates the importance of these numbers. The deficient conditions are only present for the side streets of stop-controlled intersections, and could be eliminated with signalization if warranted.

In addition to the intersection *LOS* estimates, the *P&NS* also presents estimated existing and future travel times as shown in Table 21 reproduced below.

Figure 1: P&NS Table 22 (p. 42)

Table 21: Existing and Future Travel Time (minutes)

	Morning Peak Hour				Afternoon Peak Hour			
	EB Existing	WB Existing	EB 2045	WB 2045	EB Existing	WB Existing	EB 2045	WB 2045
ClearGuide	3.62	3.41	N/A	N/A	4.15	3.82	N/A	N/A
VISSIM	3.65	4.07	3.75	4.39	4.59	4.35	5.79	4.67

Source: Iteris ClearGuide, SRF Consulting Group, 2022
Notes: N/A = not applicable. EB = eastbound. WB = westbound.

Future modeled travel times are longer than base year travel times.

Figure 2: P&NS Table 20 (p. 41)

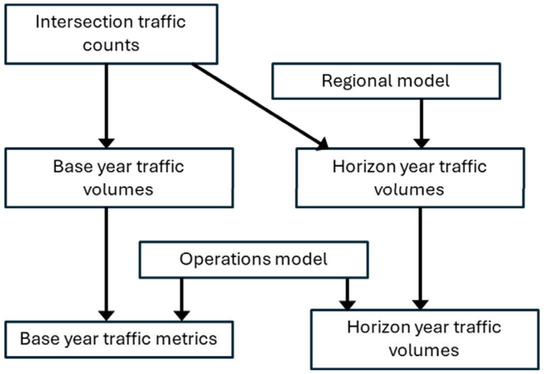
Table 20. Existing and Forecasted Future Intersection Capacity Analysis

Intersection	Traffic Control[1]	Morning Peak Hour		Afternoon Peak Hour	
		Existing	2045	Existing	2045
Thomas Avenue	SSSC	15.4 sec LOS A / C	22.3 sec LOS A /C	35.9 sec LOS A / E	93.9 sec LOS A / F
Sheridan Avenue	SSSC	0.2 sec LOS A / A	0.3 sec LOS A / A	0.2 sec LOS A / A	0.6 sec LOS A / A
Russell Avenue	SSSC	12.8 sec LOS A / B	16.0 sec LOS A / C	19.5 sec LOS A / C	60.8 sec LOS A / F
Queen Avenue	SSSC	4.6 sec LOS A / A	5.5 sec LOS A / A	4.7 sec LOS A / A	15.4 sec LOS B / C
Penn Avenue	Signal	29.2 sec LOS C	29.5 sec LOS C	32.3 sec LOS C	32.0 sec LOS C
Newton Avenue	SSSC	5.8 sec LOS A / A	5.4 sec LOS A / A	5.6 sec LOS A / A	5.7 sec LOS A / A
Morgan Avenue	Signal	8.1 sec LOS A	9.1 sec LOS A	10.6 sec LOS B	9.7 sec LOS A
Logan Avenue	SSSC	5.1 sec LOS A / A	5.3 sec LOS A / A	0.8 sec LOS A / A	0.5 sec LOS A / A
James Avenue	SSSC	15.4 sec LOS A / C	18.7 sec LOS A / C	26.9 sec LOS A / D	32.5 sec LOS A / D
Humboldt Avenue	Signal	9.1 sec LOS A	8.6 sec LOS A	15.4 sec LOS B	11.3 sec LOS B
Frontage Road Mid-Block Crossing	SSSC	0.4 sec LOS A / A	0.6 sec LOS A / A	4.9 sec LOS A / A	19.1 sec LOS B / C
Van White Memorial Boulevard	Signal	11.7 sec LOS B	12.1 sec LOS B	16.3 sec LOS B	20.4 sec LOS C
Bryant Avenue	Signal	8.8 sec LOS A	10.2 sec LOS B	8.3 sec LOS A	31.8 sec LOS C
W Lyndale Ave/I-94 On-Ramp	Signal	22.9 sec LOS C	26.0 sec LOS C	22.9 sec LOS C	43.3 sec LOS D
E Lyndale Ave/I-94 Off-Ramp	Signal	26.6 sec LOS C	25.2 sec LOS C	26.9 sec LOS C	32.7 sec LOS C
Oak Lake Avenue/ Border Avenue	Signal	12.3 sec LOS B	16.1 sec LOS B	15.5 sec LOS B	19.8 sec LOS B

[1] SSSC = side-street, stop-controlled; overall / worst approach, Signal = traffic signal; overall intersection
Source: SRF Consulting Group, 2022
Notes: Red areas denote poor level of service
LOS results represent the operations averaged over the peak hour

The vehicle mobility metrics in the tables reproduced above were developed by applying two different transportation models in sequence – 1) a regional model and 2) an operations model. The relationship between the two models is illustrated in Figure 3. The operations model was used in estimating all of the metrics.

Figure 3: Vehicle Mobility Metric Estimation in the P&NS



In the *P&NS*, the regional model application was limited. The P&NS states:

> Forecasted volumes (2045 AADTs) were developed from Hennepin County's Travel Demand Model. The outputs of the model result in an annual growth rate of 0.5 percent. (P&NS, p. 8)

It is not clear that the Hennepin County Travel Demand Model is being updated regularly. The only documentation I found is a set of PowerPoint slides from 2007.[1] The much more recent County's Transportation Mobility 2040 Plan states:

> Hennepin County conducted a comprehensive travel demand forecasting analysis primarily utilizing the regional activity based model provided by the Metropolitan Council. (p. 2-36)[2]

This implies that Hennepin County is not relying on a separate county model anymore. I am assuming that the Met Council model is the appropriate regional model for analyzing transportation alternatives going forward, and I am focusing on the Met Council model.

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[1] https://www.dot.state.mn.us/traffic/data/mtdmcc.html, Hennepin County Transportation Systems Plan (HC-TSP) Traffic Forecasting Model, 3/15/07.

[2] https://mc-379cbd4e-be3f-43d7-8383-5433-cdn-endpoint.azureedge.net/-/media/hennepinus/business/work-with-hennepin-county/transportation-planning/comp-plan-2040-2-transportation.pdf?rev=a04f0b62324a450baf7ee53bc51b0e7f&hash=FFB56EFD3BD4A58C68D0304C4E2ABB40

In the *P&NS*, the operations model applied was VISSIM which is a microsimulation model where individual vehicles are represented.

1.1.2. Evaluation Criteria

In January 2024, MnDOT published Olson Memorial Highway Multimodal Study Evaluation Criteria ("*Criteria*"). *Criteria* auto vehicle mobility metrics include the two metrics from the *P&NS* - Intersection traffic operations and corridor travel time, plus a third metric, "local road access/street grid connectivity," that would not be modeled (*Criteria*, p. 9). The *Criteria* "Evaluation Scale" for the two modeled vehicle mobility metrics are generic. For intersection traffic operations, LOS A-B is "good," LOS C-D is "fair" and LOS E-F is "poor." For corridor travel time, greater than a 20% decrease is "good," greater than a 20% increase is "poor," and lesser changes are "fair." This travel time criterion is problematic because calming traffic will be required to meet the primary walkability and bikeability needs, and this will necessarily increase corridor travel times. This is particularly important because the P&NS documents that current average speeds are considerably higher than the posted speed limit as shown in this excerpt from p. 8.

Figure 4: P&NS Excerpt Concerning Corridor Speeds

Traffic speed was analyzed using data collected by MnDOT in May 2022 via radar to determine 85th percentile speeds (Table 1). The 85th percentile speed estimates illustrate that vehicles are exceeding the posted speed limit of 40 miles per hour (mph) in those areas by up to 10 mph. Most vehicles traveling through the corridor operate at a speed greater than the posted limit. There are currently three (3) speed limits posted in the corridor:

- **50 mph:** western Study boundary to Thomas Avenue
- **40 mph:** Thomas Avenue to I-94
- **25 mph:** I-94 to eastern Study boundary

Table 1: Traffic Speed

Data Collection Point	Pace (10 mph)		85th Percentile Speed	
	Eastbound	Westbound	Eastbound	Westbound
Between Knox Avenue and Irving Avenue	39-48 mph	38-47 mph	49 mph	49 mph
Between Van White Memorial Boulevard and Bryant Avenue	40-49 mph	38-47 mph	50 mph	47 mph

Source: MnDOT, 2022

Therefore, the secondary vehicle travel time metric should be weighted much less than the primary needs of walkability and bikeability, and probably eliminated completely.

The first two *Criteria* vehicle mobility metrics will rely on the process shown in Figure 3 above with a sequence of two models . The *Criteria* specifies Synchro/Simtraffic as the operations model (*Criteria*, p. 9). It is possible that the 2045 traffic forecasts used in the

P&NS will carry forward, but it would be much better to apply the Met Council model with separate forecasts for each alternative.

The role of the regional model is critical in the alternatives analysis process. Operations models can fairly accurately translate traffic counts into traffic metrics, but inputting unrealistic regional model outputs for 2045 or 2050 into an operations model will result in large errors.

In the following sections, I evaluate the validity of the Met Council model for analyzing alternatives, including:

1. How well does the model match base year traffic volumes?
2. How well does the model match base year traffic speeds?
3. How realistic are modeled traffic changes between the base year and the horizon year?

2. Met Council Regional Model Base Year Validation

The Met Council model distribution package (April 2025) base scenario is labeled "Base Year (2025)." The package states: "The base year used in the TPP was based on the anticipated 2025 network." However, the socio-economic inputs for population, households and employment all are tagged "2022."

This sort of discrepancy is common in regional transportation modeling where models are updated in a multi-year process and the focus is often on the horizon year – in this case, 2050. Therefore, it is best to think of the model as intending to match 2022-2025 conditions. In this review, I compare the volume and speed data from calendar year 2024 to the base year model outputs.

More concerning than the possible differences across the time period 2022-2025, the travel behavior embodied in the Met Council model is still based on a 2010 household travel survey.[3]

[3] Cambridge Systematics, Inc. *Model Estimation and Validation Report: 2010 Travel Behavior Inventory Final Report*. Prepared for Metropolitan Council, July 30, 2015.

2.1. Traffic Volumes

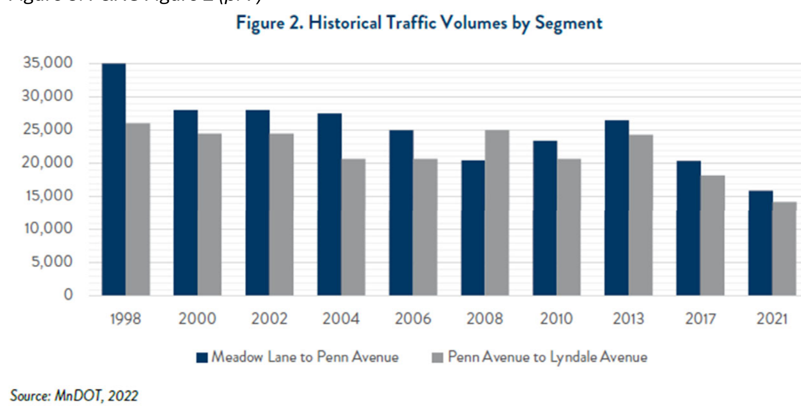
2.1.3. Olson Memorial Highway Traffic Volumes

The September 2023 Olson Memorial Highway Multimodal Study Purpose & Need Statement reviewed 20 years of traffic data in the corridor and concluded that:

> The segments analyzed were from Meadow Lane to Penn Avenue (15,900 AADT [2021]) and Penn Avenue to East Lyndale Avenue (14,200 AADT [2021]). Motorized traffic volumes in both segments have been largely trending downward over the last 20 years with overall decreases of 55 percent and 45 percent, respectively. (p. 7)

These data are summarized in the report's Figure 2 which is reproduced here. The final year shown, 2021, was an unusually low traffic volume year in many locations because it was the first full year of the Covid-10 pandemic.

Figure 5: P&NS Figure 2 (p. 7)



The MnDOT Traffic Mapping Application shows one post-2021 traffic estimate in the corridor, 16,161 for the Meadow Lane to Penn Avenue section in 2023. This is higher than the 14,248 volume for 2021, but lower than the 18,200 volume given for 2017 or for any of the previous years shown in the figure reproduced above. Therefore, the general downward trend in corridor traffic volumes has continued.

The traffic data presented above are Annual Average Daily Traffic ("AADT"). The model traffic volumes that are intended to represent Annual Average Weekday Traffic ("AAWT") volumes. Weekday traffic volumes generally are higher than weekend traffic volumes in urban areas; therefore, a small adjustment is needed to estimate AAWT from AADT. MnDOT has developed adjustment factors for different types of roadways. It labels this corridor as “High Week Day/Commuter” and I used the adjustment factors for this category to obtain a adjustment factor of 1.078. Applying this factor to the 2023 traffic count of 16,161, the estimated AAWT is 17,422 to the west of Penn Avenue. In the Study excerpt reproduced above, the estimated volume to the east of Penn Avenue was 10.7% lower than the volume to the west of Penn Avenue. Therefore, I estimate the 2023 AAWT for the segment to the east of Penn Avenue to be 15,559.

As shown in the Figure 6 below, Base 2025 model outputs are much higher – over twice as high to the west of Penn Avenue almost 3 times as high to the east of Penn Avenue.

Figure 6: 2025 Base Year Model Annual Average Weekday[4] Traffic (in thousands of vehicles)

> Findings:
>
> 1) The modeled traffic volume errors for Olson Memorial Highway are so large that the model needs significant reworking to make it useful in doing alternatives analyses in this corridor.

[4] 2024 holidays are omitted from these averages.

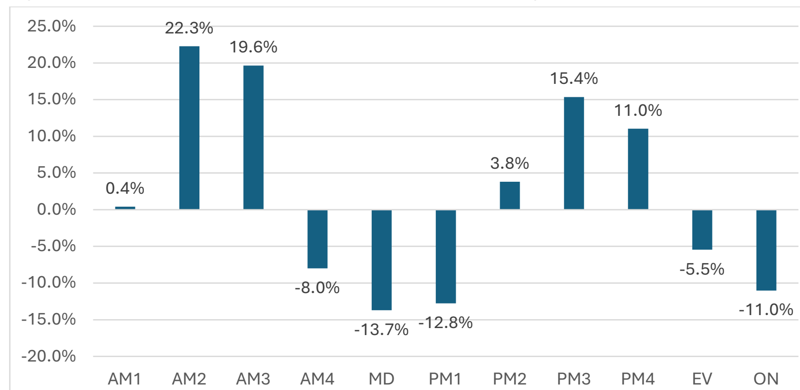
2.1.4. Regional Traffic Volumes

There are limited traffic counts in the study area, and these count are based on infrequent short-term tube counts. The gold standard for traffic counts are 24/7 automatic traffic recorder (“ATR”) stations operated by MnDOT. Most of the ATRs in the Met Council model area are on major freeways and tabulate vehicles within each lane in each hour. At these locations, the counts can be compared to model outputs for 11 separate time periods (the model estimates traffic by hour during peak periods and groups hours in off-peak periods):

- AM1 6-7 a.m.
- AM2 7-8 a.m.
- AM3 8-9 a.m.
- AM4 9-10 a.m.
- MD 10 a.m. -3 p.m.
- PM1 3-4 p.m.
- PM2 4-5 p.m.
- PM3 5-6 p.m.
- PM4 6-7 p.m.
- EV 7 p.m. - 12 midnight
- ON 12 midnight – 6 a.m.

After summing traffic volumes across lanes within each direction, but keeping express lane volumes separate, there are 118 separate location/direction/lane group records for the ATRs in the model area. In the figure below, Base 2025 model volume is totaled across the records and compared to the sum of 2024 traffic counts. As shown in Figure 7, the model overestimates the traffic volume in the morning and afternoon peak periods and underestimates the traffic volume during off-peak periods.

Figure 7: Model Traffic Volume Relative ATR Traffic Volume by Model Time Period

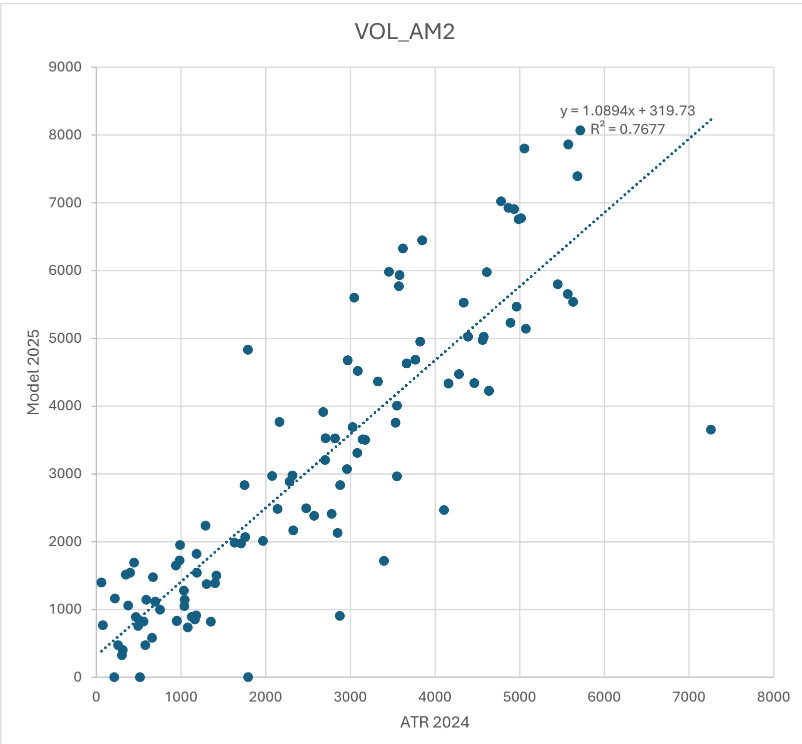


Findings:

2) The regional traffic volume errors are so large that the model needs significant reworking to make it useful in doing alternatives analyses anywhere in the region.

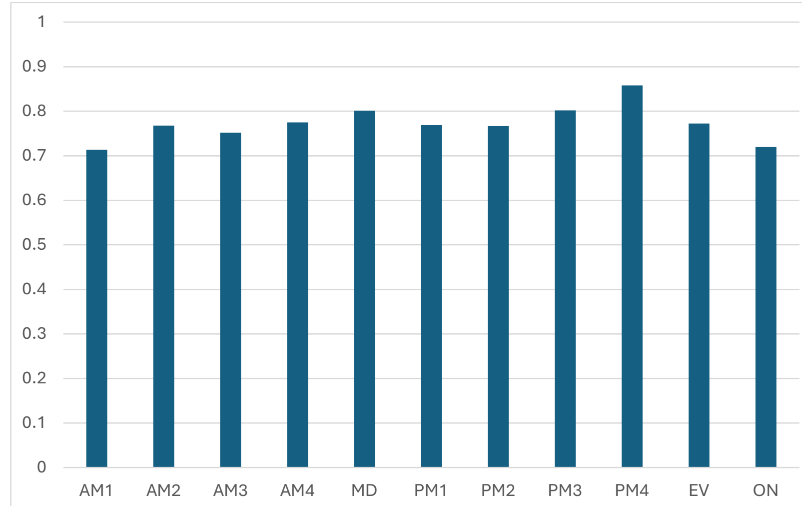
Figure 8 shows the separate observations for the worst time period – AM2 (7-8 a.m.) where the average model volume is 22.3% greater than the counted volume.

Figure 8: AM2 (7-8 a.m.) Model Volume vs. ATR Counts for Each Location/Direction/Lane Group



As shown in the graphic, the best fit line is 1.09 times the ATR count + 320. There is a positive correlation between the model outputs and the ATR counts, but the R-squared statistic is not very good (0.77) and. (An R-squared of 1.00 represents a perfect fit between the traffic counts and the model outputs.) Figure 9 below shows the R-squared for each of the 11 time periods.

Figure 9: Model Volume vs ATR Volume R-Squared by Model Time Periods



The value of the statistic is similar in every period, and never as high as is desirable.

Findings:

3) The model matches traffic volumes poorly in each of the 11 time periods.

2.2. Traffic Speeds

Although 24/7 traffic counts are limited to the set of ATR stations, 24/7 traffic speeds are available for all major roadway segments through data collection from cell phones that are treated as “probes.”[5]

Figures 10 and 11compare average 2024 non-holiday weekday speeds for each hour to model outputs for the section of Olson Memorial Highway between Penn Avenue and West Lyndale Avenue.

Figure 10: Eastbound Olson Memorial Highway Average Weekday Speed (Including Stops) – Penn to West Lyndale

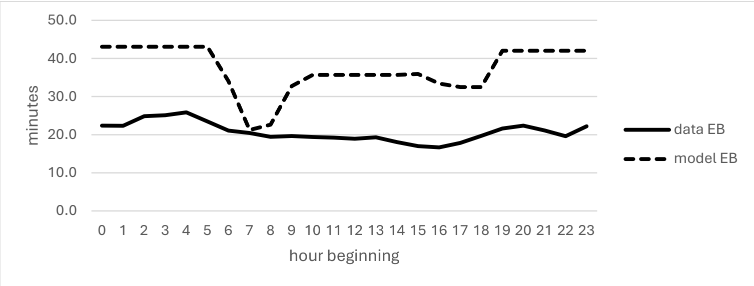
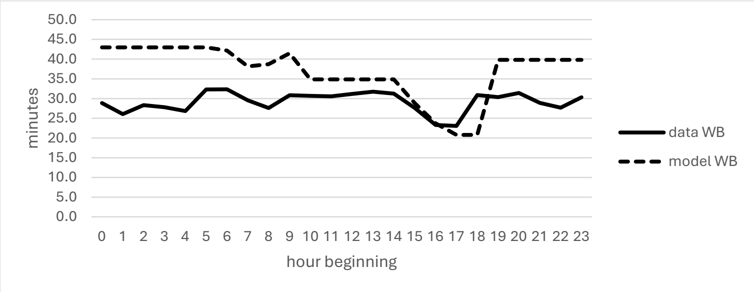


Figure 11: Westbound Olson Memorial Highway Average Weekday Speed (Including Stops) – Penn to West Lyndale



[5] Traffic volumes also can be estimated from cell phone data. However, estimating traffic volumes requires a model to expand the sample of vehicles with cell phones and location services turned on to the entire population of vehicles. This process is not made public and introduces errors making the data somewhat unreliable. In contrast, the sample vehicle speeds generally represent the speeds of the entire population, particularly in congested conditions when cars are following other cars.

As shown in the above figures, the model greatly exaggerates Olson Memorial Highway speeds in the section from Penn Avenue to West Lyndale Avenue during off-peak periods because it assumes that traffic will move freeway without stopping at traffic signals (which are not modeled). The P&NS reports that there are 6 traffic signals in this section at Penn Avenue, Morgan Avenue, Humboldt Avenue, Van White Memorial Boulevard, Bryant Avenue, and at West Lyndale Avenue (p. 41).

<u>Findings</u>:

4) The model overestimates Olson Memorial Highway traffic speeds because it fails to account for stops at traffic signals.

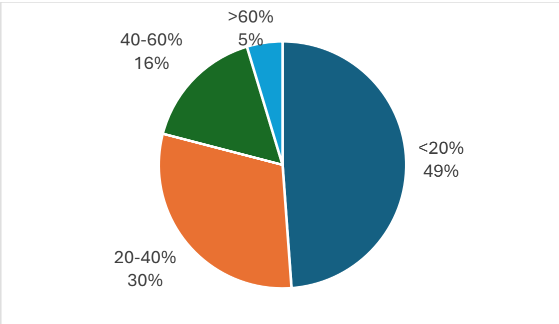
The model matches average travel speeds better in the peak direction in the peak period, i.e., eastbound in the morning and westbound in the afternoon. However, this also is problematic because it demonstrates that modeled travel times are overly sensitive to traffic volumes that are well below capacity in all time periods, with small differences in modeled volumes translating into large changes in modeled speeds. In the data, there is little variation in traffic speed throughout the 24-hour period.

<u>Findings</u>:

5) Modeled traffic speeds on Olson Memorial Highway are overly sensitive to higher traffic volumes that are well below capacity.

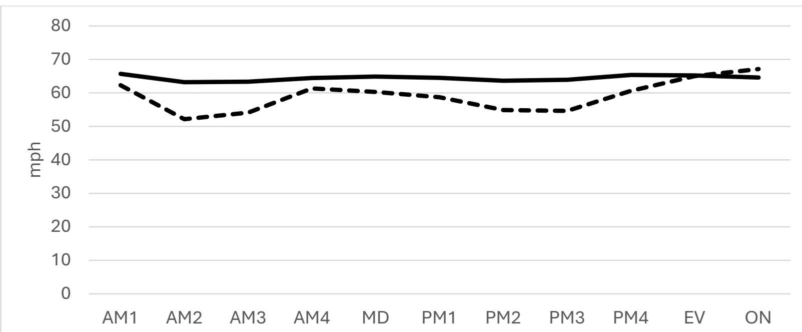
In general, modeled speeds are more accurate for freeways where traffic signals delays are not present, but the model does not account for severe congestion well. For the set of ATR locations, actual speeds at about half the locations vary by less than 20% across all time periods, i.e., congestion slows traffic by less than 20% relative to free-flow conditions. About 30% of the locations vary by 20-40% across time periods, and about 20% vary by more than 40%, with a small number having speed reduction of more than 60% during one or more periods. (Figure 12)

Figure 12: ATR Locations Classified by Maximum Hourly Congestion Speed Reduction in Speed Data (Calculated Separately for Each Direction)



Figures 13 through 16 show average speeds and modeled speeds for each mode time period, averaged for each of the groups shown in Figure 12.

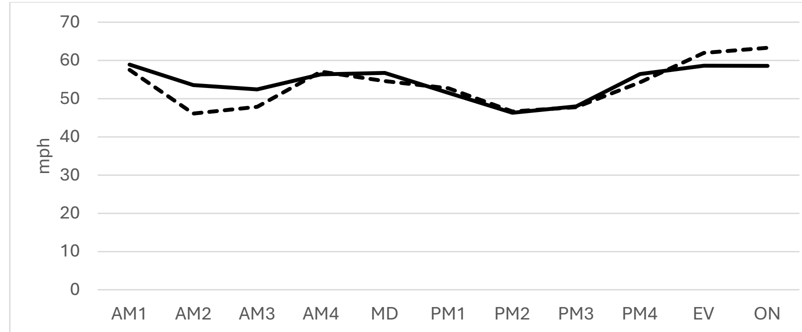
Figure 13: Modeled Speed vs. Data Average for ATR Locations with Maximum Speed Reduction of Less than 20%



Key: AM1-AM4 6-10 am MD 10 am–3 pm PM1-PM4 3-7 pm, EV 7 pm–12 am ON 12 am-6 am

As shown in Figure 12, the model generally underestimates speed for the half of ATR locations that are generally uncongested, and also estimates more peak period speed reduction than what is in the data.

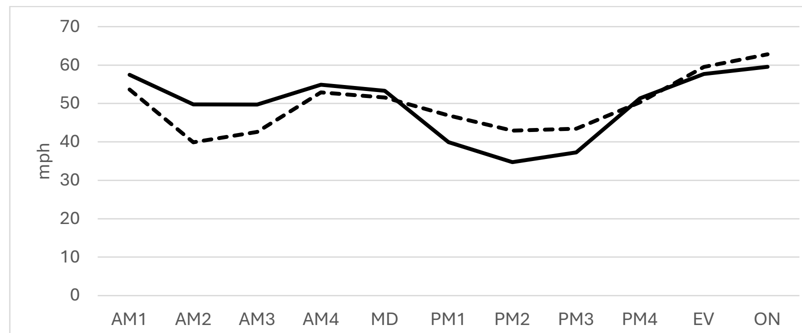
Figure 14: Modeled Speed vs. Data Average for ATR Locations with Maximum Speed Reduction of 20-40%



Key: AM1-AM4 6-10 am MD 10 am–3 pm PM1-PM4 3-7 pm, EV 7 pm–12 am ON 12 am-6 am

A shown in Figure 13, for the group of ATR locations with maximum speed reductions of 20-40%, the model generally matches speeds well, especially in tracking afternoon speed reductions. The model overestimates morning speed reductions somewhat.

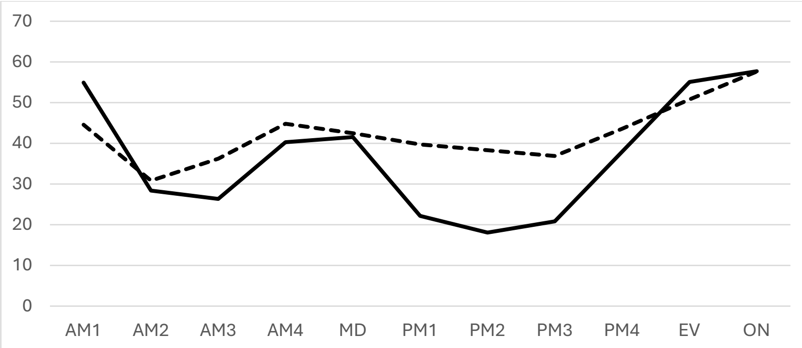
Figure 15: Modeled Speed vs. Data Average for ATR Locations with Maximum Speed Reduction of 40-60%



Key: AM1-AM4 6-10 am MD 10 am–3 pm PM1-PM4 3-7 pm, EV 7 pm–12 am ON 12 am-6 am

For the group of ATR locations with maximum speed reductions of 40-60% (Figure 14), the model somewhat overestimates morning congestion and underestimates afternoon congestion.

Figure 16: Modeled Speed vs. Data Average for ATR Locations with Maximum Speed Reduction of Greater than 60%



Key: AM1-AM4 6-10 am MD 10 am–3 pm PM1-PM4 3-7 pm, EV 7 pm–12 am ON 12 am-6 am

For the small number of ATR locations with maximum speed reductions of greater than 60% shown in Figure 15, the model significantly underestimates afternoon congestion.

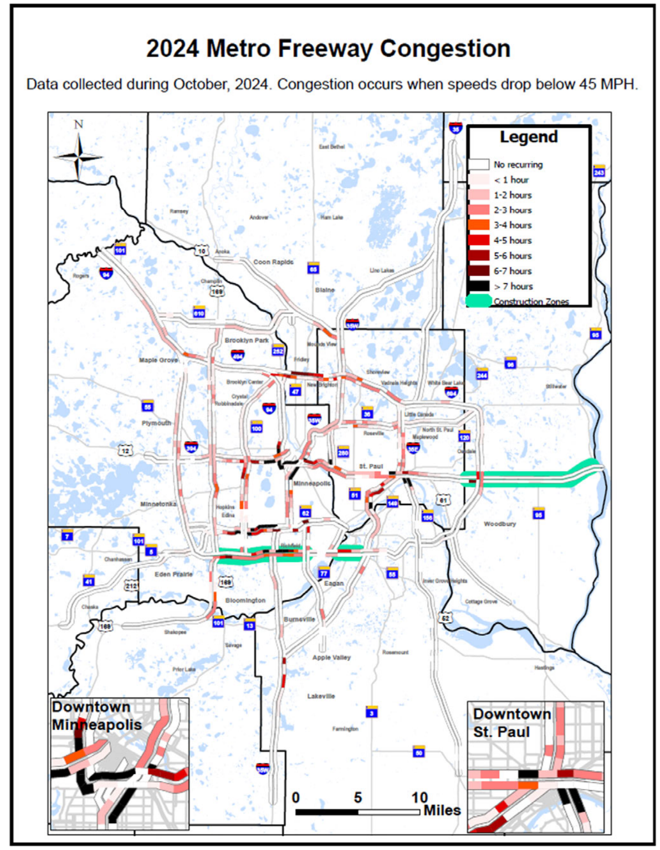
<u>Findings</u>:

6) The model appears to smooth out the level of freeway congestion, showing more peak period congestion than is present at uncongested locations, and less congestion than is present at severely congested locations. The model also overestimates morning congestion in many locations.

2.3. Freeway Traffic Volume/Speed Relationships

The relationships between traffic volume and speed are critical in traffic modeling; therefore, locations where both volume and speed data are available are especially useful in evaluating model performance. The most congested freeway segments in the region do not necessarily overlap with ATR locations. Figure 17 reproduces a MnDOT graphic showing the most congested roadway segments in the region.

Figure 17: https://www.dot.state.mn.us/measures/congestion.html



One of the most congested segments shown in Figure is I-394 eastbound parallel to the Olson Memorial Highway. The MnDOT graphic shows more than 7 hours of daily congestion west of I-94. ATR 326 is location on I-394 to the west of the Penn Avenue interchange and near to but west of the most congested I-394 segment. As demonstrated below, the regional model does not match conditions at this location well.

Before drilling down to the data this location, I discuss freeway traffic volume/speed relationships in general. As discussed in Section 1, regional travel demand models are used to estimate vehicle mobility metrics in roadway alternatives analyses. The most critical vehicle mobility metrics involve travel speed or travel time. Published metrics often include vehicle volumes as well, but these are secondary metrics because they do not directly affect users. Modeled traffic volumes are important primarily because the models use traffic volume estimates as the basis for speed and travel time estimates.

When stuck in traffic, it is natural to think that the traffic throughput is very high. However, that is not the case. The *Highway Capacity Manual* ("HCM") describes three different operations regimes. The highest speed and the highest throughput are achieved together in *undersaturated* flow conditions. In *oversaturated* (congested) conditions, both speed and traffic throughput are significantly lower. The third regime, *queue discharge flow*, is a transitional stage when traffic flow gradually returns from oversaturated to undersaturated flow conditions. The HCM descriptions of the three traffic flow regimes are:

1) *Undersaturated Flow* – Traffic flow during an analysis period (e.g. 15 min) is specified as undersaturated when the following conditions are satisfied: (1) the arrival flow rate is lower than the capacity of a point or segment, (b) no residual queue remains from a prior breakdown of the facility, and (c) traffic flow is unaffected by downstream conditions.

   Uninterrupted-flow facilities operating in a state of undersaturated flow will typically have travel speeds within 10% to 20% of the facility's free-flow speed, even at high flow rates, under base conditions (e.g., level grades, standard lane withs, good weather, no incidents). Furthermore, no queues would be expected to develop on the facility.

2) *Oversaturated Flow* – Traffic flow during an analysis period is characterized as *oversaturated* when any of the following conditions is satisfied: (a) the arrival flow rate exceeds the capacity of a point or segment, (b) a queue created from a prior breakdown of a facility has not yet dissipated, or (c) traffic flow is affected by downstream conditions.

   On uninterrupted-flow facilities, oversaturated conditions result from a bottleneck on the facility. During periods of oversaturation, queues form and extend backward

from the bottleneck point. Traffic speeds and flows drop significantly as a result of turbulence, and they can vary considerably, depending on the severity of the bottleneck. . . On freeways, vehicles move slowly through a queue, with periods of stopping and movement. Even after the demand at the back of the queue drops, some time is required for the queue to dissipate because vehicles discharge from the queue at a slower rate than they do under free-flow conditions. Oversaturated conditions persist within the queue until the queue dissipates completely after a period of time during which demand flows are less than the capacity of the bottleneck.

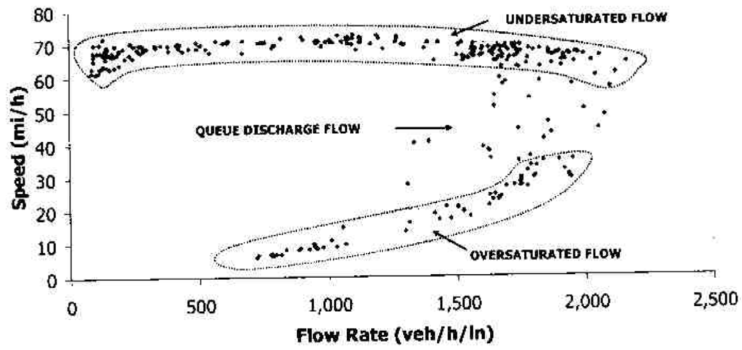
3) *Queue Discharge Flow* – Queue discharge flow represents traffic flow that has just passed through a bottleneck and, in the absence of another bottleneck downstream, is accelerating back to the facility's free-flow speed. Queue discharge flow is characterized by relatively stable flow as long as the effects of another bottleneck downstream are not present.

   On freeways, this flow type is typically characterized by speeds ranging from 35 mi/h up to the free-flow speed of the freeway segment. Lower speeds are typically observed just downstream of the bottleneck. Depending on horizontal and vertical alignments, queue discharge flow usually accelerates back to the facility's free-flow speed within 0.5 to 1 mi. downstream of the bottleneck. The queue discharge flow rate from the bottleneck is lower than the maximum flows observed before the breakdown.[6]

Figure 18 reproduces an HCM graphic illustrating volume/speed data for the three traffic regimes.

[6] Transportation Research Board. Highway Capacity Manual, 7th Edition, 2022, p. 2-14 – 2-15.

Figure 18:Three Traffic Operations Regimes – Reproduced from the HCM



Source: California Department of Transportation, 2008.
Note: I-405, Los Angeles, California.

As documented below, the regional model matches the volume/speed relationship fairly well for undersaturated flow conditions but does a poor job for the other two regimes that are of more importance.

The model uses a static assignment algorithm (“STA”) that treats every road segment as independent of other segments and estimates travel speeds and delay for each segment based on the volume-to-capacity (V/C) ratio for that segment by applying Bureau of Public Roads (BPR) equation.

$$t_i = t0_i * \left((1+\alpha * \left(\frac{v_i}{c_i} \right)^{\beta} \right)$$

where:

t_i = congested flow travel time on link i

$t0_i$ = free-flow travel time on link i

v_i = volume of traffic on link i per unit of time

c_i = capacity of link i per unit of time

α = alpha coefficient

β = beta coefficient

The Met Council model freeway parameters are:)

- Capacity = 1950 passenger car equivalent vehicles (“PCE”) per lane per hour (trucks weighted as 2.0 autos)
- α = 0.4
- β = 8.0

In the example of eastbound I-394 west of Penn Avenue, 15.8% of the daily modeled traffic at this location is comprised of trucks; therefore, the model capacity in vehicles per lane per hour is 1684 vehicles per lane per hour adjusted from 1950 PCE per lane per hour. The road is coded with a free-flow speed of 64 mph. Applying the parameters given above, Figure 19 shows the regional model’s volume/speed relationship for freeway segments.

Figure 19: I-394 ATR Model Volume/Speed Relationship (per Lane)

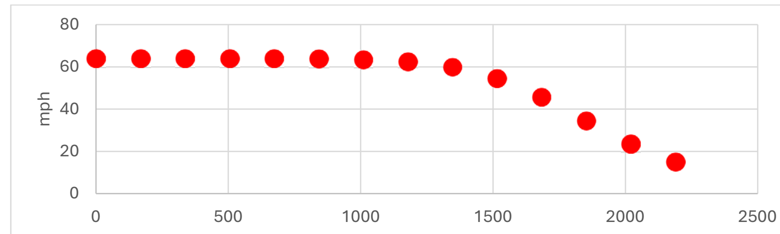
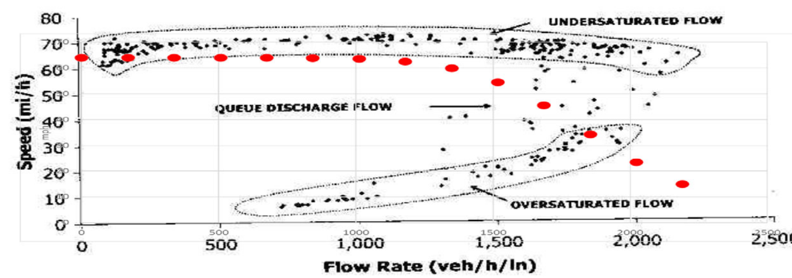


Figure 20 overlays the model volume/speed relationship on the graphic showing the three traffic operations regimes.

Figure 20: I-394 ATR Model Volume/Speed Relationship Relative to Three Traffic Operations Regimes



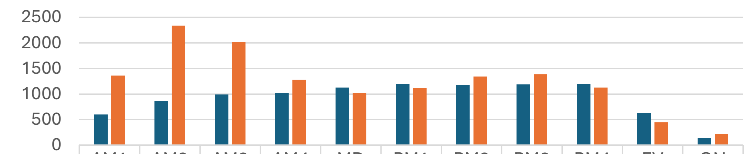
Source: California Department of Transportation, 2008.
Note: I-405, Los Angeles, California.

As shown in Figure 20:

- Model speeds are fairly realistic for low flow rates because there are no delays and the model also estimates no delays.
- At the higher traffic range in undersaturated flow conditions, the model overestimates delays.
- The model fails to represent oversaturated flow conditions when congested speeds are below 30 mph – the most important case.
- Modeled speeds below 30 mph are present only with impossibly high traffic volumes of over 1750 vehicles per lane per hour (or 2000 PCE), and these modeled volumes and speeds should be considered to be model errors.

ATR 326 traffic count data illustrates how the model fails to properly model traffic congestion in congested time periods. 2024 data were not published by MnDOT for this location, so 2023 data are used. There are 3 eastbound lanes at this location, and total traffic volumes have been divided by 3 so that the numbers are in the same terms of vehicles per lane per hour shown in the previous graphics.

Figure 21:Eastbound I-394 Vehicles per Lane per Hour - ATR and Model By Time Period



	AM1	AM2	AM3	AM4	MD	PM1	PM2	PM3	PM4	EV	ON
ATR	600	861	993	1024	1125	1194	1177	1190	1194	624	139
model	1361	2339	2021	1278	1019	1112	1343	1386	1126	445	223

As shown in the figure, the model grossly overestimates the morning peak period traffic volumes at this location, with more than twice the counted volume in the AM1 and AM3 periods and by an even worse factor of 2.7 in the AM2 period (7-8 a.m.) These high traffic volumes are not only much too high, but are impossibly high as discussed above – even if the facility was operating, in undersaturated flow conditions.

Findings:

7) The model outputs impossibly high traffic volumes during congested time periods.

In sharp contrast, the ATR volume never exceeds 1200 vehicles per lane per hour (about 1400 PCE). Despite, or perhaps because, this is one of the most congested freeway sections in the region, the road is operating under saturated flow conditions and traffic volume never achieves the theoretical maximum built into the model.

Traffic speeds on the ATR segment are consistent with saturated flow conditions, and speeds are even lower in the data for the two freeway segments downstream. Figure 22 shows average weekday hourly speeds for the ATR segment and the two more congested segments to the east. Figure 23 shows model outputs for the same segments.

Figure 22:Eastbound I-394 Weekday Hourly Speed Data (2024)

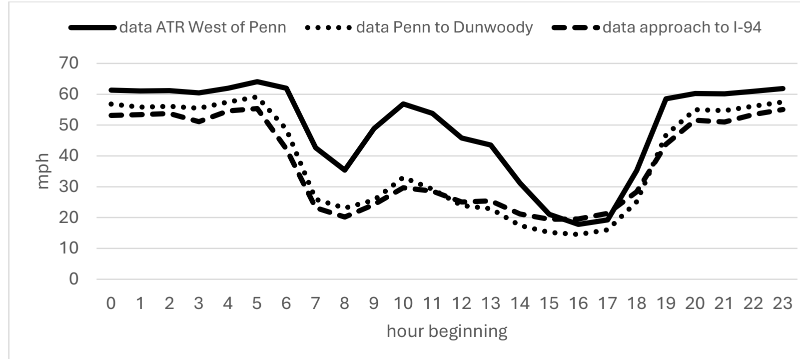
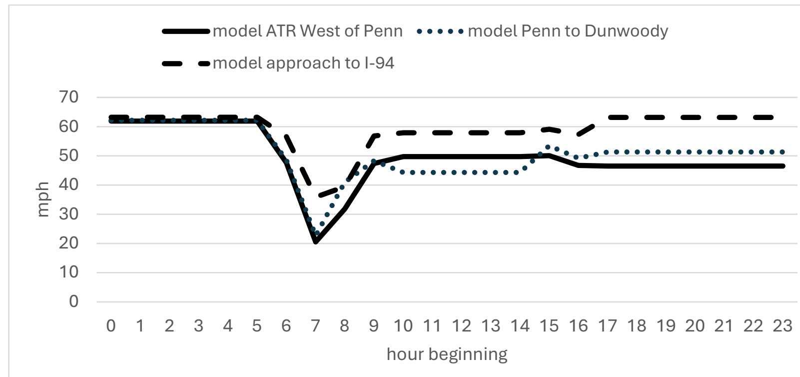


Figure 23:Eastbound I-394 Weekday Model Outputs

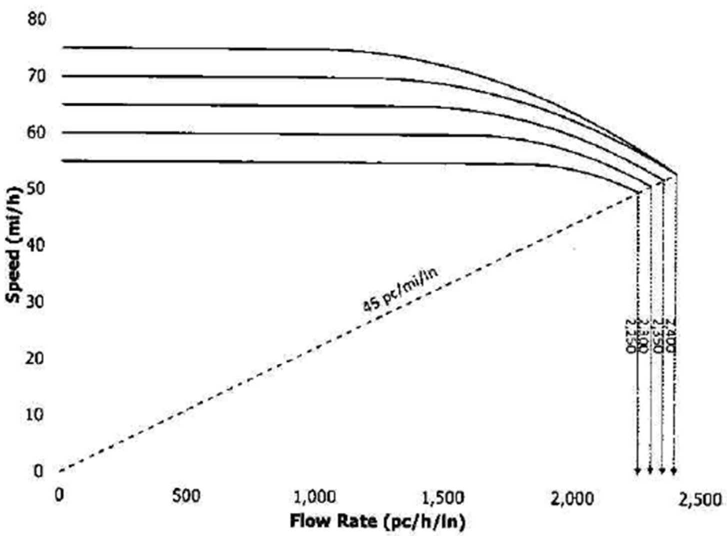


There are significant differences between the speed data and the model speeds, including:

- The speed data shows severe congestion in the afternoon peak period with speeds as low as 15 m.p.h., but the model shows little congestion then.
- In the data, the ATR segment west of Penn Avenue is the least congested of the three segments; in the model, it is the most congested segment

The HCM provides a model that relates traffic volume and speed for both undersaturated and oversaturated flow conditions that is useful in understanding volume-speed relationships on freeways (Figure #).

Figure 24: HCM Exhibit 12-7 Speed-Flow Curves for Basic Freeway Segments



The solid lines at the top represent undersaturated flow for different free-flow speeds. As shown, there is little delay for traffic volumes of less than 1500 vehicles per lane per hour.

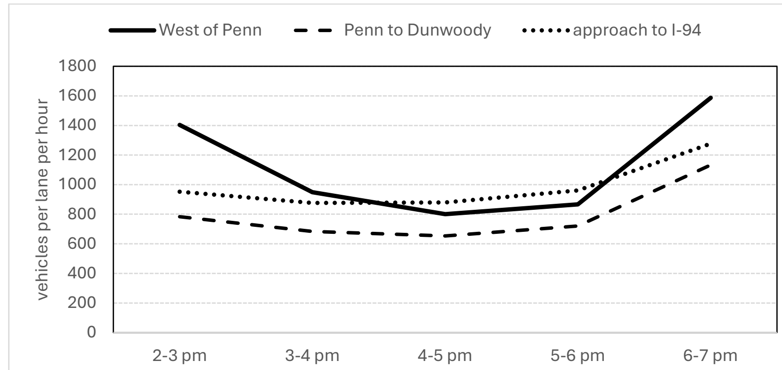
The dashed line represents oversaturated flow. The value of 45 pc/mi/ln (passenger cars per mile per lane) is the density given in the *HCM* for the threshold between a congested level of service ("LOS") E condition and a failed LOS F (oversaturated) condition. At a speed of 0 mph (left end of dashed line), traffic is stalled and the flow rate is also 0. At a speed of

50 mph (right end of dashed line), the flow is 45 x 50 = 2,250. However, this volume is unstable and generally breaks down quickly into oversaturated flow conditions. For this reason, managed lane systems target a lower sustainable volume of 1600 – 1650 vehicles per lane per hour.[7]

Intermediate values are shown along the dashed line. In the graphic, the estimated speed for a traffic flow of 1200 vehicles per lane in saturated flow conditions is about 25 mph – although a traffic flow of 1200 vehicles per lane in undersaturated flow can operate at free-flow speeds.

Applying the HCM model, estimated throughput for the 3 segments in the afternoon peak period is shown in Figure 25.

Figure 25: Estimated Eastbound I-394 Afternoon Peak Vehicle Throughput Based on Observed Speed Estimated Using HCM Model (2024)



In the most congested segment between Penn and Dunwoody, the average speed from the data is only 15-17 mph between 2 p.m. and 6 p.m., and the estimated throughput is only about 800 vehicles per lane per hour throughout this 4-hour period. The HCM throughput estimate for the segment west of Penn Avenue is lower than the almost 1200 vehicles per lane per hour in the 2023 ATR data; however, the speeds may also have been lower in 2023 than in 2024.

[7] https://ops.fhwa.dot.gov/freewaymgmt/publications/frwy_mgmt_handbook/revision/jan2011/mgdlaneschp8/sec8.htm

Findings:

8) Traffic throughput on congested freeways is much lower than assumed in the regional model.

There is a second reason why throughput and speed for particular freeway segments can be lower than modeled. Both the regional model and the HCM model treat road segments as independent, but in reality, the traffic flow west of Penn Avenue is constrained by the more severe congestion to the east of Penn Avenue. A more accurate model would account for the affects of bottlenecks. These bottleneck affects include:

- Upstream – lower speeds and lower throughput as traffic backs up behind the bottleneck
- Downstream – higher speeds and higher throughput as the bottleneck "meters" the traffic flow and allows undersaturated flow past the bottleneck

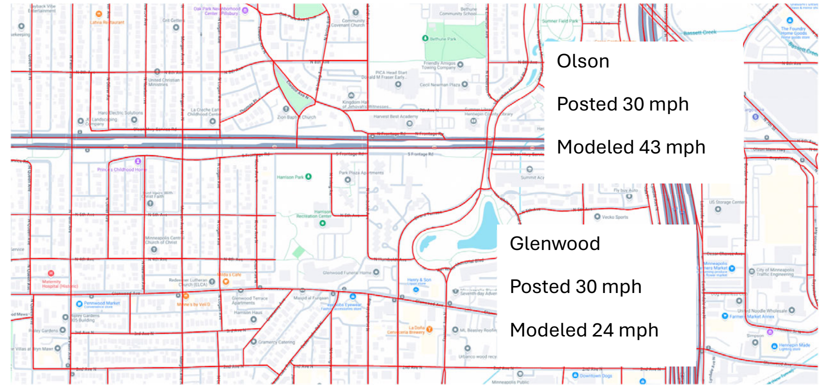
Findings:

9) The model fails to account for the affects of bottlenecks on upstream and downstream freeway segments.

2.4. Street Grid Coding Issues

Not all local streets are in the model. In some regional models, local streets that carry significant amounts of traffic are omitted, and this can cause the traffic volumes for the streets that are modeled to be overestimated. In this model, as shown in Figure 26, it appears that the streets that carry through traffic in the area surrounding Olson Memorial Highway are modeled. If alternatives are modeled that reconnect the grid, it will be important to include those connections in the model.

Figure 26: Olson Memorial Highway Area Street System (Model Links in Red



Coded speeds are an issue in this model. As shown in Figure 26, the posted speeds for the parallel streets Olson Memorial Highway and Glenwood Avenue in the eastern end of the study are 30 mph, but the free-flow modeled speeds are 43 mph and 24 mph, respectively. (The free-flow speed is the maximum model speed; congested model speeds are lower.) The large model speed differential will cause the model to over-assign Olson Memorial Highway and under-assign Glenwood Avenue. This partially explains why modeled speeds and traffic volumes are too high for Olson Memorial Highway as is documented above.

These modeled speeds are calculated from a lookup table based on the area type and road class for each segment. Olson Memorial Highway is road class #2, "trunk highway," and Glenwood Avenue is road class #4, "Major Road." The area type is "residential core."

Figure 27: Model free-flow speeds

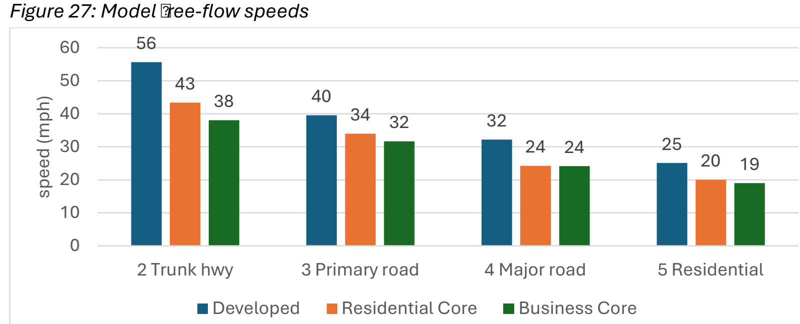
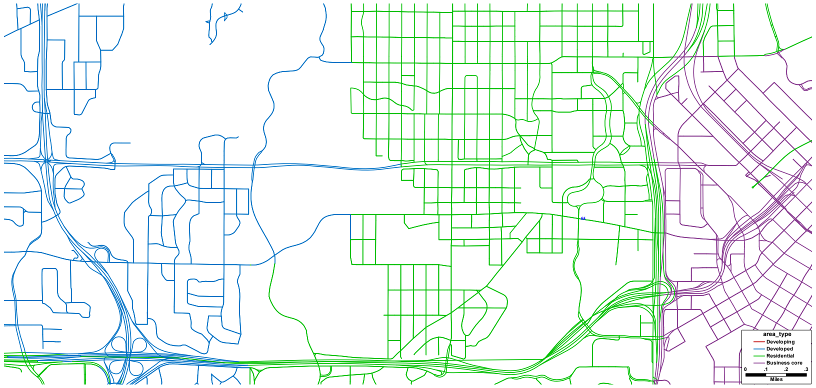


Figure 28 shows the area types in vicinity of the study area. The study area is in the green area, “residential core,” with higher model speeds than in the purple “business core” area, and lower model speeds than in the blue “developed” area.

Figure 28: Model Area Types



It would be desirable to apply posted speeds for all street segments, but that has been considered to be impractical in most regions, and the use of lookup tables is standard practice. However, with a greater emphasis on pedestrian safety and other quality-of-life issues, many jurisdictions have lowered speed limits in many areas, and these model lookup tables are often out of date. For example, the Minneapolis Vision Zero Action Plan 2023-2025 emphasizes lowering speeds and the word “speed” occurs 81 times in the document.

Furthermore, as discussed earlier in this report, average speeds on urban streets with traffic signals are always lower than posted speeds because of stoppage time.

3. Proper Accounting for Induced Traffic

In general, freeway expansion causes induced travel as measured in vehicle miles traveled (“VMT”). A review of the induced travel research by Handy and Boarnet (2014) concluded that induced travel is real, and that the magnitude is enough to prevent capacity expansion from reducing congestion:

> Thus, the best estimate for the long-run effect of highway capacity on VMT [vehicle miles traveled] is an elasticity close to 1.0, implying that in congested metropolitan areas, adding new capacity to the existing system of limited-access highways is unlikely to reduce congestion or associated GHG [greenhouse gas] in the long-run.[8]

It is critical that roadway alternatives modeling properly accounts for induced travel. Otherwise, benefits of road expansion will be exaggerated. The induced travel process also works in reverse, Urban freeway downsizing will reduce VMT. If these affects are not properly analyzed, the benefits of downsizing will be underestimated.

Regional models often fail to properly account for induced travel. The Rocking Mountain Institute has developed the SHIFT Calculator[9] to estimate how much induced travel will result from urban freeway widening in all areas of the U.S. As shown in Figure #, the Calculator estimates that in the Twin Cities region, each added freeway lane mile of capacity will add and additional 4 to 7 million VMT per year.

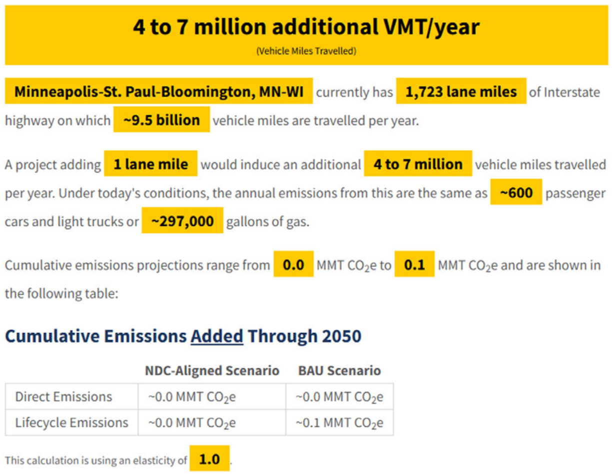
The Shift Calculator also estimates induced travel for “other freeways & expressways or other principal arterials (Class 2 or 3 facility), These roadways are estimated to add 3 to 5 million VMT per year per additional lane mile in the Twin Cities region.

Comparing the 2050 model networks for the No Build and Build alternatives (including all planned regional road projects), the Build network has 82 more freeway lane miles and 20 fewer principal arterial lanes miles (likely due to some upgrading).

Applying the midpoint estimates from the Calculator (5.5 million VMT per year for freeways and 4 million VMT per year for principal arterials) and dividing by 340 to convert to an average weekday, the Shift Calculator estimates 1.08 million additional VMT per day in the Build alternative (Figure 29).

[8] Handy, Susan and Marlon G. Boarnet. Impact of Highway Capacity and Induced Travel on Passenger Vehicle Use and Greenhouse Gas Emissions: Policy Brief prepared for California Air Resources Board, September 30, 2014.
[9] https://shift.rmi.org/

Figure 29: Shift Calculator Estimate of Induced Travel From Adding Freeway Capacity



The actual difference in the model VMT outputs between the two alternatives is 345,000 per day, i.e., 32% of the Shift Calculator estimate. Understanding why the model underestimates induced travel requires looking at the mechanisms that underly induced travel (Figure 30).

Figure 30: Induced/Reduced Traffic Mechanisms (Credit: Ian Lockwood)

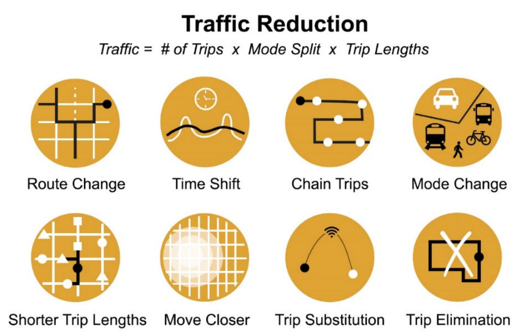


Table 1 is an initial assessment of the importance of each mechanism, how well it is modeled, and how the model might be enhanced.

Table 1: Preliminary Assessment of Model's Capability to Account for Induced Ravel

Mechanism	Importance	How well modeled	Model enhancement?
Route change	Most important	Limited by inaccurate times	More accurate speeds[1]
Shorter trip lengths	2nd most important	Limited by inaccurate times	More accurate speeds[1], check feedback procedures[2]
Mode choice	Important	Could check sensitivity[3]	More accurate speeds[1], check feedback procedures[2], possibly adjust parameters[3].
Time shift	Important for peak congestion; less important for VMT	Could to check sensitivity[3]	More accurate speeds[1], check feedback procedures[2], possibly adjust parameters[3].
Chain trips		Could check sensitivity[3]	
Trip substitution		Could check sensitivity[3]	
Trip elimination		Could check sensitivity[3]	
Move closer		Not modeled	

[1]As documented in previous sections, freeway speeds should be faster off-peak and slower peak, on average, and non-freeway speeds should be slower.

[2]Model includes feeding back congested travel times to the demand models including destination choice and mode choice, However, the Method of Successive Averages ("MSA") process is not fully converging after 4 iterations.

[3]Activity-based models ("ABM") including the Met Council model are theoretically better at modeling some induced travel mechanisms than the previous generation of trip-based models; however, whether this capability is realized depends on the equations and coefficients. The sensitivity of each ABM component to travel time can be evaluated by changing all network travel times by a fixed percentage, e.g. 10%, and running the component separately and comparing results.

The goal is to increase induced travel in the model relative to the SHIFT Calculator standard from the current 32% to as close to 100% as possible.

<u>Findings</u>:

10) The model underestimates the effect of freeway capacity on induced travel.

4. Proposed Model Fixes

4.1. Connecting the Dots

As documented above, I have found:

1) The modeled traffic volume errors for Olson Memorial Highway are so large that the model needs significant reworking to make it useful in doing alternatives analyses in this corridor.
2) The regional traffic volume errors are so large that the model needs significant reworking to make it useful in doing alternatives analyses anywhere in the region.
3) The model matches traffic volumes poorly in each of the 11 time periods.
4) The model overestimates Olson Memorial Highway traffic speeds because it fails to account for stops at traffic signals.
5) Modeled traffic speeds on Olson Memorial Highway are overly sensitive to higher traffic volumes that are well below capacity.
6) The model appears to damp down the level of freeway congestion somewhat, showing more peak period congestion than is present at uncongested locations, and less congestion than is present at severely congested locations. The model also overestimates morning congestion in many locations.
7) The model outputs impossibly high freeway traffic volumes during congested time periods.
8) Traffic throughput on congested freeways is much lower than assumed in the regional model.
9) The model fails to account for the affects of bottlenecks on upstream and downstream freeway segments.
10) The model underestimates the effect of freeway capacity on induced travel.

These findings can be summarized as different problems in peak and off-peak periods:

- Peak periods –
  - model overestimates freeway speeds
  - model overestimates freeway throughput
  - model underestimates diversion to streets
  - feedback to travel demand is too weak to fully account for induced travel
- Off-peak periods –
  - model underestimates freeway speeds
  - model overestimates street speeds
  - model overestimates diversion to streets

4.2. Improving Freeway Modeled Speeds and Traffic Volumes

The issues are primarily due to the Static Traffic Assignment ("STA") process because it does not represent the three traffic regimes discussed above or account for bottlenecks as documented above.

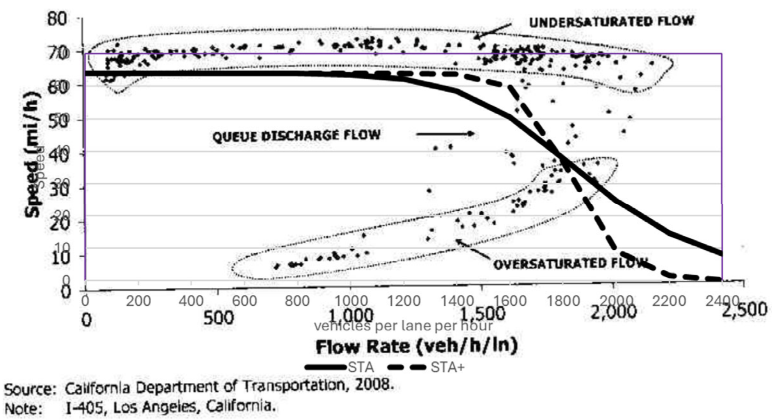
Microsimulation models including the VISSIM model used in the *P&NS* and the Synchro model planned for the next planning stage can represent the three traffic flow regimes and account for bottlenecks. However, microsimulation models require much more data and have much longer simulation times than STA, and therefore are only applied in small subareas.

Dynamic Traffic Assignment ("DTA") also can represent the three traffic flow regimes and account for bottlenecks. DTA requires less data than microsimulation and has computation times that are intermediate between microsimulation and STA. Most DTA applications are an a subarea level. I have demonstrated that DTA is practical at a regional level in smaller regions in a case study in the Portland Maine region.[10] However, this region is large enough that regional DTA is impractical.

[10] Marshall, Norman. Forecasting the impossible: The status quo of estimating traffic flows with static traffic assignment and the future of dynamic traffic assignment, *Research in Transportation Business & Management*, Volume 29, 2018, 85-92. https://www.sciencedirect.com/science/article/pii/S2210539517301232?via%3Dihub

Therefore, I plan to rework the STA process in what I call "Capacity-Constrained STA" or "CCSTA" where the STA algorithm is made to constrain modeled freeway throughput to freeway capacity. Figure 31 illustrates how CCSTA will shift the volume/speed relationship from the current model.[11]

Figure 31: I-394 Volume/Speed Relationship Relative to Three Traffic Operations Regimes – Current Model Solid Line and CCSTA Dashed Line



The much steeper CCSTA curve will eliminate most of the over-capacity traffic assignments. For example, at a volume of 2000 PCE per lane per hour, a rate that approaches the theoretical capacity for undersaturated flow, the model speed would drop from the current 25 mph to 9 mph. This change would percolate down through other model components and result in reduced demand through the feedback process. This would result in better accounting for induced demand in expansion alternatives.

Special attention will be paid to capacity constraint on freeway ramps where regional models often grossly-over-assign traffic because low speeds on short ramps are translated into only short delays.

At lower throughput levels, CCSTA speeds are higher than the current model. For example, at 1600 PCE per lane per hour, the model speed will increase from 51 mph to 60 mph. This better represents undersaturated flow data. This change also will result in more realistic daily metrics. In several freeway expansion studies I have reviewed, much of the calculated

[11] The final CCSTA parameters may be different than those applied in Figure 31.

daily time savings is from reducing off-peak throughput from one moderate value to another, e.g. from 1600 PCE per lane per hour to 1200 PCE per lane per hour. The modeled off-peak time savings in these models is largely nonexistent in reality.

CCSTA cannot represent severe oversaturated flow congestion where speeds are less than 20 mph because the STA algorithm can only output one speed for a given volume. In these cases, the model will continue to overestimate traffic throughput, but by a much smaller margin than the current model.

4.3. Other Model Enhancements

Other model enhancements will address two issues that are discussed in previous sections:

1) Non-freeway speeds will be coded more realistically.
2) The feedback process will be strengthened to converge more quickly.