Ramsey County 4 to 3 Lane Conversion Study

RAMSEY COUNTY, MN

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1.0 Introduction

Alliant Engineering, Inc. evaluated the feasibility and potential benefit of four-lane to three-lane conversions (or other applicable "road diet" configurations) of 22 roadway segments throughout Ramsey County.

1.1 Study Purpose

The purpose of the conversion study was to evaluate the feasibility of implementing road diets on 22 Ramsey County and St. Paul roadway segments from both an operational perspective and an ease of implementation perspective, as well as identifying where a road diet would be most beneficial. The County identified 22 segments to consider. Alliant, along with members of the Technical Advisory Committee, developed a set of metrics and criteria for this evaluation. A final step in the study was to develop a priority list for potential implementation.

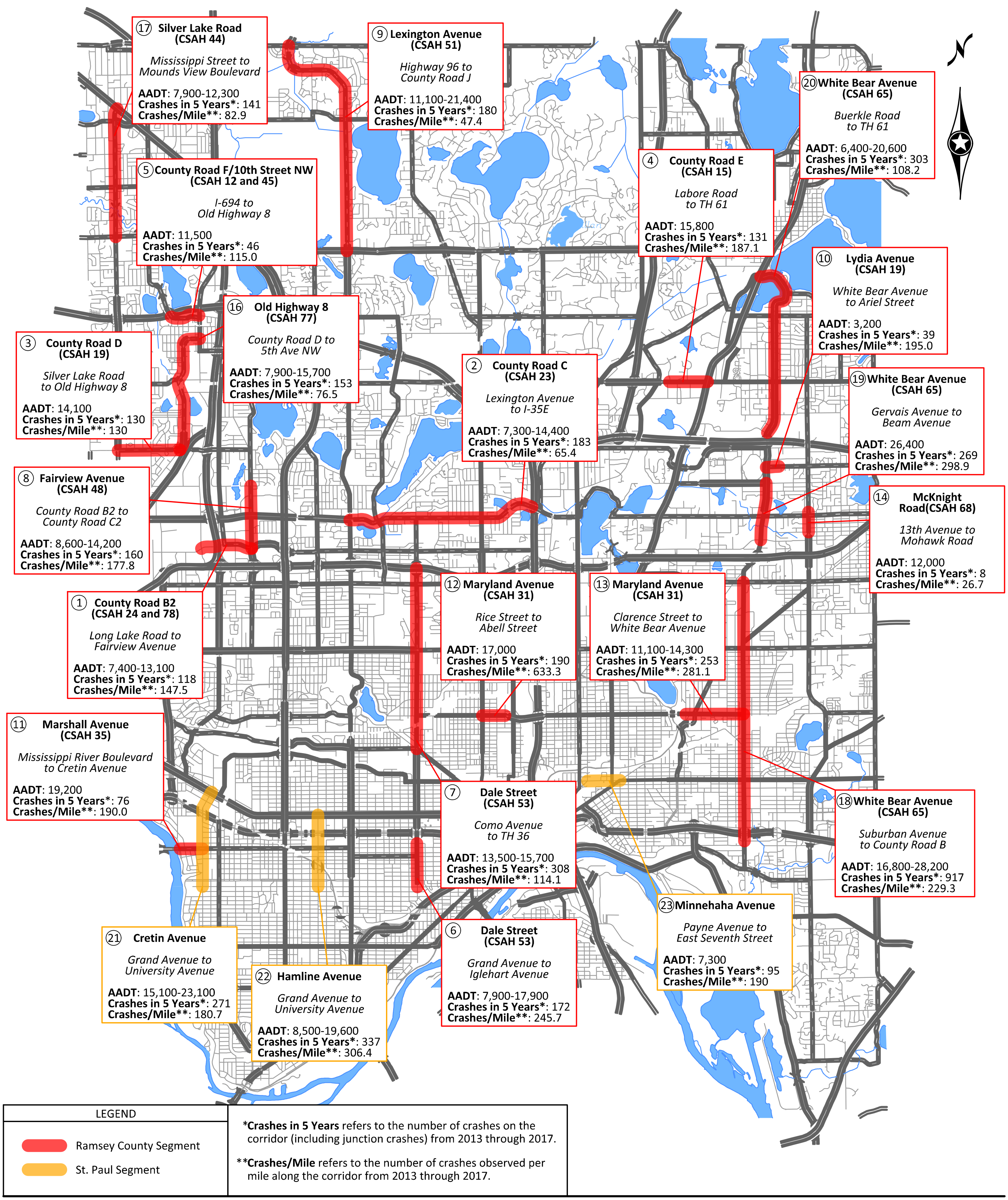
1.2 Background

Three-lane roadways have been successfully implemented for decades, but recent years have seen an increase in popularity and an upsurge in interest to convert existing four-lane roadways to 3-lane. This is due to the variety of benefits that three-lane roadways bring; and, in some cases the ease in which conversions are often able to be executed.

Four-lane undivided roadways have a variety of issues. According to the *2015 MnDOT Traffic Safety Fundamentals Handbook*, four-lane undivided roadways have the highest urban crash rate of any road configuration in Minnesota. The "double lane threat" to pedestrians leads to unsafe crossings, and in general these types of roadways are not multi-modal friendly. Turning traffic on the mainline can cause motorists to weave between both lanes. Speeds are often high, and the speed differentials between lanes reduce safety.

1.3 Description of Location

Segments evaluated were located in Ramsey County, Minnesota and in the following 12 cities: Arden Hills, Gem Lake, Little Canada, Maplewood, Mounds View, New Brighton, North St. Paul, Roseville, St. Paul, Shoreview, Vadnais Heights, and White Bear Lake. The study included 19 segments under Ramsey County jurisdiction and 3 segments under St. Paul jurisdiction. The segments range from 0.2 miles to 3.8 miles long and are highlighted in **Figure 1**. It should be noted that segment 15 was initially part of the study but was removed since a conversion is part of a larger capital project that will be built in 2020.



Four-Lane to Three-Lane Conversion Study

Figure 1
Project Overview

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2.0 Literature Search

The purpose of the literature search was to further understand the benefits and impacts of road diets (i.e. four-lane to three-lane conversions), and to identify key factors that should be evaluated when screening the segments under consideration. Literature search sources are listed in **Appendix A**. Key sources of information were found in the *FHWA Road Diet Informational Guide* and *ITE Road Diet Handbook*.

2.1 Benefits of Conversion

There are several benefits of converting four-lane roadways to three-lane roadways, including safety, operational, multimodal, and quality of life benefits.

2.1.1 Safety Benefits

Key safety benefits include the following:

- Crash Reduction
- Safety Benefits for Pedestrians and Bicyclists
- Reduction in Speed and Speed Differentials
- Improved Sight Distance

According to the *FHWA Road Diet Informational Guide*, many road diet safety benefits are achieved through reducing the number of vehicle-to-vehicle conflict points, as shown in **Figure 2**. The number of vehicle conflict points at mid-block locations decreases from 6 to 3 when comparing four-lane roadways to three-lane. The number of conflict points at an intersection is also halved, from 8 conflict points with a four-lane to 4 conflict points with a three-lane when the cross street is a two-lane roadway.

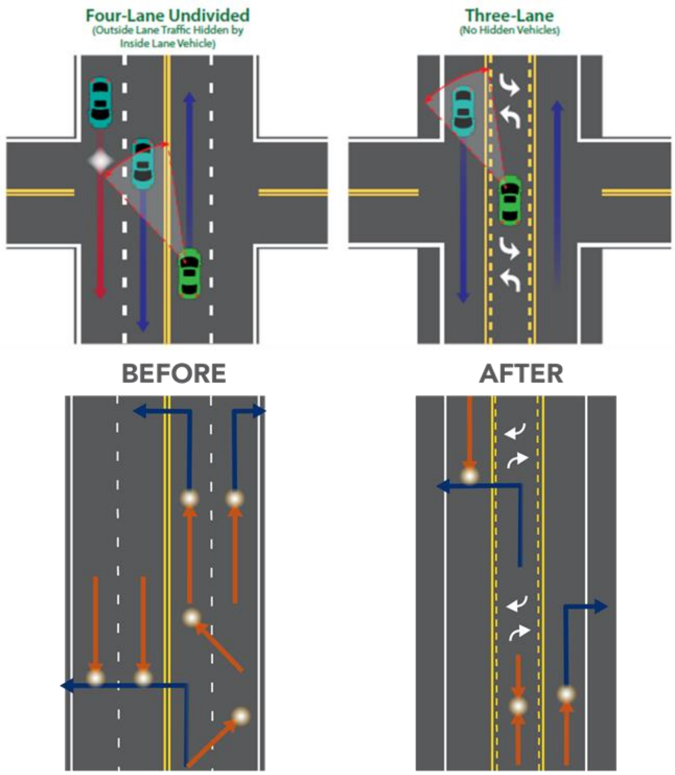


Image Source: FHWA

Figure 2. 4-Lane vs 3-Lane Vehicle Conflict Points

Pedestrians and bicyclists also see benefits on three-lane roadways. Decreasing the number of through lanes in either direction to one eliminates the multiple/double lane threat when crossing, as shown in **Figure 3**. When crossing on a roadway with more than one through lane, a stopped vehicle can block the view of a pedestrian from vehicles in the other lane. Both pedestrians and bicyclists also benefit from decreased speeds.

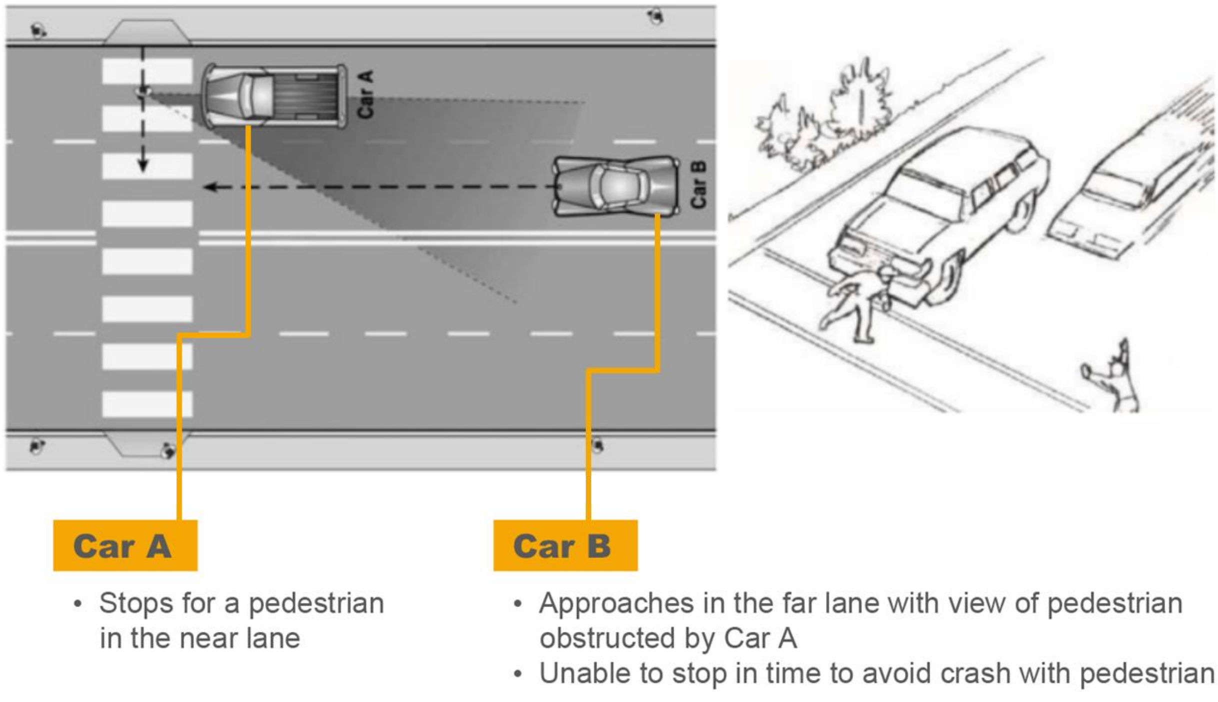


Image source: FHWA

Figure 3. Multiple/Double Lane Threat

By moving all through traffic to one lane, motorists are forced to go the speed of the slowest vehicle which has been shown to reduce overall speeds. A study, *4-Lane to 3-Lane Conversions*, by the Iowa Department of Transportation also noted an improvement in emergency response times on roadways that were converted.

2.1.2 Operational Benefits

Key operational benefits include the following:

- More Comfortable for Side-Street Traffic to Enter Roadway
- Consistent Traffic Flow
- Two-Way Center Left Turn Lanes
- Reduced Delay at Signals (in certain situations)
- More Space for Pedestrians and Bicyclists
- Opportunity for Refuge Islands
- Can Provide Dedicated Pull-Out Spaces for Buses

Separating left turns from through-lanes can greatly reduce delay at intersections. This is especially the case at signalized intersections, where inefficient split signal phasing is often used on shared lane approaches. A three-lane cross section has also been shown to reduce delays at side-streets and can make entering the roadway more comfortable as there are fewer lanes of traffic to cross. Two stage left turns are possible at unsignalized access points. The reduction in speeds and speed differentials allows for consistent traffic flow.

Pavement once used for a travel lane can be re-allocated for a variety of different modes when a four-lane to three-lane conversion takes place. This pavement is usually reallocated for peds and bikes. Even if this space isn't converted to a bike lane or sidewalk, added parking or a wide shoulder can add a much-needed buffer between pedestrians and vehicles, and bicyclists can be passed more safely if motorists move closer to the center lane when approaching. The two-way center left turn lane can be replaced with a median pedestrian refuge island at locations where left turns do not need to take place, such as at mid-block locations.

Buses can experience or create operational difficulties in some three-lane configurations; however, providing space for buses to pull out of the travel way benefits general purpose traffic and should be provided as space permits.

2.1.3 Quality of Life Benefits

The livability of a roadway can be improved through all of the benefits mentioned previously. Slower traffic and efficient operations can improve comfort for all motorists and non-motorists. Adding sidewalk space or bike lanes and encouraging these modes adds quality of life benefits for these users in the community.

2.2 Factors to Consider

While a road diet conversion of a roadway can provide a variety of benefits, it is important to understand the impacts to be sure the roadway is well-suited for the conversion. If a roadway segment does not have the right characteristics, a conversion can actually hinder safety and operations.

Key factors to consider when determining feasibility of conversion include:

- Crash Patterns
- On-Street Parking
- Roadway Function
- Traffic Volumes
- Transit and Freight
- Lane Utilization
- Access Points/Management
- Roadway Width

The following sections detail what must be considered when screening a potential candidate for conversion.

2.2.1 Crash Patterns

Historical crash data should be analyzed to determine if crash patterns are of the type that can be addressed by a conversion. Conversions from four-lane to three-lane have been proven to lower rear end, sideswipe, head-on, and pedestrian crashes.

2.2.2 On-Street Parking

The need for parking along the corridor should also be considered. Several study segments operate with reduced capacity due to on-street parking during off peak hours. It is important to understand parking demands and if it can be provided with the new configuration. In some cases, continuous on-street parking can be provided as a result of a conversion.

2.2.3 Roadway Function

Roadways serve two major functions: access and mobility. Interstates and principal arterials provide the highest degree of vehicular mobility but are limited in providing land access for vehicles and other modes. Local streets provide a high degree of access for all modes with less vehicular mobility. It is important to understand what changes, if any, in access and mobility may be a result of a lane conversion.

2.2.4 Traffic Volumes

There are many aspects of traffic volumes to evaluate when considering a conversion. The following existing conditions (as well as projected characteristics) should be evaluated:

- Average Daily Traffic (ADT)
- Peak Hour Volumes
- Directional Distribution
- Turning Volumes and Patterns

<u>Average Daily Traffic</u>
Roadways with high Average Daily Traffic (ADT) are not appropriate for a three-lane configuration. Studies have shown that a three-lane cross section can operate with an acceptable delay per vehicle and levels of service with ADTs between 8,500 and 24,000. FHWA (Federal Highway Administration), advises that 3-lane roadways with ADTs above 20,000 are reaching capacity and may experience excessive delay and queues resulting in poor levels of service.

<u>Peak Hour Volumes</u>
It is also important to understand what portion of the ADT occurs during peak hours. FHWA suggests that roadways with peak hour volumes above 875 vph are likely to see an increase in delay and reduction in level of service on a three-lane roadway. Volumes at or below 750 vph have a high probability of success as a three-lane roadway.

<u>Directional Distribution</u>
Much like how peak hour volumes should be considered, the directionality of volumes must also be considered. If the directional distribution is not 50/50, an analysis should be performed in the direction of heavier traffic flow.

<u>Turning Volumes and Patterns</u>
Roadways with a high number of left turns are generally good candidates for conversion. The number of turning movements at driveways should be carefully evaluated to understand if a conversion is appropriate.

2.2.5 Transit and Freight

There are some trade-offs for transit and freight when a roadway is converted. Generally, these types of vehicles use the outer lane for stopping, so it may be necessary to provide a wide shoulder to accommodate their needs in select areas.

2.2.6 Lane Utilization

Vehicular traffic lane use should be examined to determine the extent of lane utilization. In many instances four lane undivided roadways may not be providing the expected capacity due to traffic favoring specific lanes in hopes of avoiding turning vehicles. Three lane roadways can provide operational improvements for roadways with significant turning movements along a corridor.

2.2.7 Access Points/Management

When analyzing a corridor for conversion, potential conflict points in the two-way center left turn lane (TWCLTL) must be considered. Closely spaced (i.e. offset) minor streets and/or driveways and offset driveways do not usually work well with a shared center left turn lane according to the *FHWA Road Diet Informational Guide*. As shown in **Figure 4**, this is due to turning vehicles trying to occupy the same space within the center turn lane.

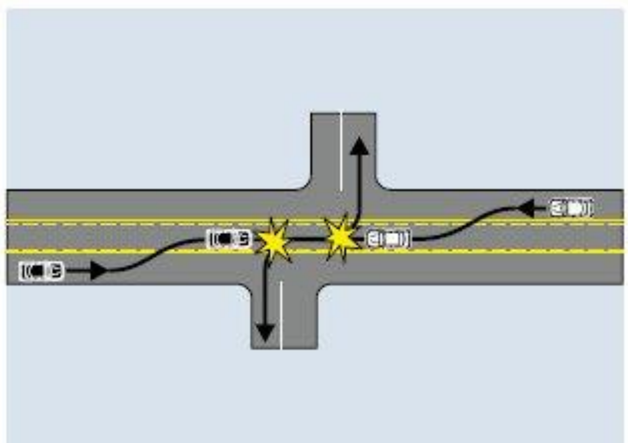


Image source: FHWA

Figure 4. Offset Driveway Conflict in TWCLTL

2.2.8 Roadway Width

Many four-lane to three-lane conversion projects can occur within the existing right-of-way with striping. It is important to know the roadway width to understand three-lane conversion options, for example, what amount of parking or bicycle space may be accommodated.

2.3 Conclusions

There are significant benefits that can be achieved by implementing a road diet. These benefits include improved safety for users, in particular for pedestrians and bicyclists. Operational benefits can be realized with the addition of two-way center left turn lanes which can lead to more consistent traffic flow and less delay at both signalized and unsignalized intersections. While a road diet conversion of a roadway can provide a variety of benefits, it is important to understand the impacts to be sure the roadway is well-suited for the conversion. If a roadway segment does not have the right characteristics, a conversion can hinder safety and operations.

3.0 High-Level Screening Analysis

The next phase of the project included a high-level screening analysis. The purpose of this analysis was to better understand the segment characteristics and how a potential lane reduction would impact each segment and determine the difficulty and benefits of converting each study segment from four lanes to three lanes (or some other similar configuration). This analysis was used to help identify eight segments for further detailed analysis, covered in **Section 4**.

3.1 Existing Conditions

Each segment was field reviewed by Alliant Engineering in October 2019. A video recording was created for each study segment which captured the latest segment characteristics including lane configurations, posted speeds, curbside uses, etc. Other data sources were accessed to obtain existing conditions data and are listed in **Table 1**. Additionally, certain points of interest (such as religious institutions, schools, and cemeteries) were documented as they can affect corridor behavior and or ability to implement geometric modifications. Detailed segment characteristics maps were created based on collected data to summarize existing conditions and are provided in **Appendix B**.

Table 1. Data Sources

Source	Segment Data
MnDOT Traffic Mapping Application	MnDOT Official AADT
St. Paul Compass	Traffic volume and speed data within the City of St. Paul
Spack Solutions	Traffic volume data collected for Ramsey County
Google Earth and Streetview	Verification of data including lane geometry, roadway width, speed limits, curbside uses
StreetLight Data	Traffic volume levels and directionality, prevailing speed, pedestrian volume levels, and bicycle volume levels
Metro Transit	Transit route information including stop location and frequency
Minnesota Geospatial Commons	Transit boarding/alighting data
MnCMAT	Crash history prior to 2016
Ramsey County	Crash history from 2016 to October 2019, pavement condition index, truck routes, future bicycle lanes, right-of-way

3.2 Screening Methodology and Criteria

3.2.1 Feasibility Considerations

To determine the complexity of a 4-lane to 3-lane conversion, a feasibility analysis was completed to understand which segments could be expected to be converted easily and which would be more difficult.

To capture varying characteristics within the individual roadway segments, such as lane configuration/roadway width and posted speed limits, the 23 segments were broken down into a series of sub-segments; 49 in total.

Several criteria were considered, and each subsegment was summarized as either "Likely Feasible," "Further Study Needed," and "Further Study Needed, Likely Above Capacity." Feasibility screening results can be found in **Appendix C**.

The following feasibility criteria were considered:

- **Road Width and Curbside Uses.** If a roadway has existing curbside uses such as on-street parking, loading zones, and transit stops, and, based on usage it is preferred they remain, then a wider road width is required than for a road with no curbside uses. If a road is 39 feet wide or less, no curbside uses can be accommodated with a 3-lane configuration (assuming a minimum of two 11' travel lanes, a 10' median, and 8' parking lane). If a road is at least 48 feet wide it can accommodate curbside uses on both sides of the road (assuming a minimum of two 11' travel lanes, a 10' median, and two 8' parking lanes). Anything in between could accommodate curbside uses on one side. It should be noted that if a segment moves towards implementation, close coordination with Metro Transit will take place to accommodate transit operation needs.
- **Annual Average Daily Traffic (AADT).** As a three-lane roadway approaches 17,000 vehicles per day, a capacity analysis is needed to better understand the roadway capacity and expected traffic operations. Each segment is unique in terms of the number of access points, controlled intersections, generators and land uses that affect overall roadway capacity. Therefore, segments with less than 16,000 AADT were deemed to have a low impact and high probability they would operate acceptably with little need for detailed analysis prior to implementation. Segments with 16,000-18,000 AADT were deemed to have a moderate impact and moderate probability they would operate acceptably and should have detailed analysis prior to implementation. Segments with greater than 18,000 AADT were deemed to have a high impact and low probability they would operate acceptably and detailed analysis prior to implementation is strongly recommended.
- **Directional Peak Hour Volume.** In addition to considering AADT, the directional peak hour volume must also be considered. Some corridors have highly directional traffic, or high peak hour volumes, or both. The theoretical capacity of a three-lane roadway is roughly 750 vehicles per hour per travel lane. Each segment is unique in terms of the number of access points, controlled intersections, generators and land uses that affect overall roadway capacity. Therefore, 750 vehicles per hour per travel lane was used as a starting point for evaluating roadway capacity. Segments with less than 700 vehicles per hour per travel lane deemed to have a low impact and high probability they would operate acceptably with little need for detailed analysis prior to implementation. Segments with 700-800 vehicles per hour per travel lane were deemed to have a moderate impact and moderate probability they would operate acceptably and should have detailed analysis prior to implementation. Segments with greater than 800 vehicles per hour per travel lane were deemed to have a high impact and low probability they would operate acceptably and detailed analysis prior to implementation is strongly recommended.
- **Other Considerations.** Some considerations that could not be quantified were also taken into account. Adjacent segment configuration on either end of the study segment was noted since this provides some context to operations with similar traffic flows. Density of access

points, signalized intersections, railroad and trail crossings, and other unique segment characteristics were considered when assigning a feasibility conclusion. Density of access points was factored into the benefit consideration analysis.

3.2.2 Benefit Considerations

To determine the potential benefit of a 4-lane to 3-lane conversion, a benefit analysis was completed for each corridor. Scores between 1-5 were assigned based on several criteria which were then equally weighted to determine an overall score. A higher score signifies higher benefit, while a lower score signifies a lower benefit. Benefit screening results can be found in **Appendix D**.

The following benefit criteria were considered:

- **Access Density.** Roads with a high number of mid-block access points can greatly benefit from a 4 to 3 lane conversion by removing turning vehicles from a through travel lane. In some cases, such as offset driveways or multiple high-volume access points, a two-way center left turn lane could be detrimental. However, the corridors on this project that had high access density tended to have low-volume access points (i.e. single family home driveways) where a benefit would be seen. Because of this, a higher access density was assigned a higher score.
- **Prevailing Speed.** Previous studies have shown that 4 to 3 lane conversions can reduce speeds along roadways. A standard measure of prevailing speed is the 85th percentile speed of vehicles traveling on a road. This data was obtained from StreetLight Data by setting up zones at key points on each corridor and analyzing all measured speeds of vehicles crossing that point on weekdays over the course of 1 year. Corridors with high 85th percentile speeds compared to the posted speed limit were given a high benefit score.
- **Crashes.** When a roadway is converted from 4-lane to 3-lane, the number of conflict points is reduced and a reduction in crashes can be expected. Each corridor was scored based on crashes per mile, where a higher number of crashes meant a higher benefit score.
- **Pedestrian Crossing Volumes.** Pedestrians can greatly benefit from a 4-lane to 3-lane roadway conversion due to the reduced number of lanes to cross and opportunity for added pedestrian islands. Pedestrian volume levels were obtained using StreetLight Data. StreetLight Data is an on-demand mobility analytics platform that utilizes "big data" from mobile devices. The StreetLight platform provides users the ability to perform analyses such as multimodal traffic volume, speed, origin-destination, and travel time studies. While StreetLight cannot provide an accurate estimate of total pedestrian volumes, it can assign an index value to compare how each roadway segment compares to the others in the analysis. A "StreetLight Score" between 0 and 100 was assigned to each corridor based on these indexes (the corridor with the lowest index received a StreetLight Score of 0 and the highest received a StreetLight Score of 100; the corridors in between were assigned a StreetLight Score proportional to the index). Roadways with a higher number of crossing pedestrians were given a higher benefit score
- **Bicyclist Volumes.** Bicyclists can also greatly benefit from a 4-lane to 3-lane roadway conversion because there is an opportunity for space to add a bike lane or buffer. Even if the extra space isn't converted to benefit bicyclists specifically, bicyclists do benefit from lower speeds and vehicles may pass them more easily by moving toward the center turn lane. Similar to pedestrian volumes, bicyclist volume levels were obtained using

StreetLight Data. As with pedestrians, StreetLight cannot provide an accurate estimate of total bicyclist volumes; it assigns an index value relative to compare how each roadway segment compares to the others in the analysis. A "StreetLight Score" between 0 and 100 was assigned to each corridor based on these indexes (the corridor with the lowest index received a StreetLight Score of 0 and the highest received a StreetLight Score of 100; the corridors in between were assigned a StreetLight Score proportional to the index). Roadways with a higher number of bicyclist volumes were given a higher benefit score.

3.3 Screening Analysis Results

A summary of the screening analysis results are shown in **Table 2**. Corridors selected for detailed analysis are discussed in **Section 4**.

Table 2: Screening Analysis Summary

Segment	Road Segment	Study Segment Approximate Length (mi)	Municipality (s) *(Italicized if on border)*	Potential 3-Lane Scope	Segment Benefit Score	Feasibility Summary
	Ramsey County Segments					
1	**County Road B2 (CSAH 24 and 78)**	0.8 mile	Roseville	Restripe+Sig Mods	2.25	**Further Study Needed**
2	**County Road C (CSAH 23)**	2.8 miles	Roseville Little Canada	Restripe+Sig Mods	1.69	**Further Study Needed**
3	**County Road D (CSAH 19)**	1.0 mile	St. Anthony *(Hennepin Co)* *Roseville*	Restripe+Sig Mods	2.20	**Further Study Needed**
4	**County Road E (CSAH 15)**	0.7 mile	*Vadnais Heights* *Gem Lake*	Restripe+Sig Mods	1.94	**Further Study Needed, Likely Above Capacity**
5	**County Road F/10th Street NW (CSAH 12/45)**	0.4 mile	New Brighton	Restripe+Sig Mods	2.80	**Likely Feasible**
6	**Dale Street (CSAH 53)**	0.7 mile	St. Paul	M&O+Sig Mods	3.20	**Further Study Needed**
7	**Dale Street (CSAH 53)**	2.7 miles	St. Paul Roseville	M&O+Sig Mods	2.19	**Further Study Needed, Likely Above Capacity**
8	**Fairview Avenue (CSAH 48)**	0.9 mile	Roseville	Restripe+Sig Mods	2.89	**Further Study Needed**
9	**Lexington Avenue (CSAH 51)**	3.8 miles	Shoreview *Arden Hills*	Restripe+Sig Mods	1.68	**Half of Corridor Further Study Needed/Likely Over Capacity**
10	**Lydia Avenue (CSAH 19)**	0.2 mile	Maplewood	Restripe+Sig Mods	2.80	**Likely Feasible**
11	**Marshall Avenue (CSAH 35)**	0.5 mile	St. Paul	Restripe+Sig Mods	3.00	**Further Study Needed**
12	**Maryland Avenue (CSAH 31)**	0.3 mile	St. Paul	Restripe+Sig Mods	3.80	**Further Study Needed**
13	**Maryland Avenue (CSAH 31)**	0.9 mile	St. Paul	Restripe+Sig Mods	3.68	**Further Study Needed**
14	**McKnight Road (CSAH 68)**	0.3 mile	North St. Paul	Restripe	2.20	**Likely Feasible**
15	**North St. Paul Road (CSAH 29)**	0.2 mile	Maplewood			removed from study
16	**Old Highway 8 (CSAH 77)**	2.0 miles	New Brighton	Restripe+Sig Mods	1.88	**Majority of Segment Likely Feasible**
17	**Silver Lake Road (CSAH 44)**	1.7 miles	New Brighton Mounds View	Restripe+Sig Mods	1.68	**Further Study Needed**
18	**White Bear Avenue (CSAH 65)**	4.0 miles	St. Paul Maplewood	Restripe+Sig Mods	3.75	**Majority of Segment Further Study Needed, Likely Above Capacity**
19	**White Bear Avenue (CSAH 65)**	0.9 mile	Maplewood	Reconstruct	2.60	**Further Study Needed, Likely Above Capacity**
20	**White Bear Avenue (CSAH 65)**	2.8 miles	White Bear Lake	Reconstruct	2.41	**More than half of Segment Likely Feasible**
	St. Paul Segments					
21	**Cretin Avenue**	1.5 miles	St. Paul	Restripe+Sig Mods	3.23	**Majority of Segment Further Study Needed, Likely Above Capacity**
22	**Hamline Avenue**	1.1 miles	St. Paul	Restripe+Sig Mods	3.75	**Further Study Needed for Subsegments on Either End of Corridor**
23	**Minnehaha Avenue**	0.5 mile	St. Paul	M&O+Sig Mods	2.80	**Further Study Needed**

4.0 Detailed Analysis and Concept Development

Based on the screening analysis results, engineering judgement, and discussion with the project Technical Advisory Committee (see **Section 6**), the following five corridors under Ramsey County jurisdiction and three corridors under St. Paul jurisdiction were selected for further detailed analysis and are shown in **Figure 5**:

- Segment 2 – County Road C between Lexington Avenue and I-35E
- Segment 7 – Dale Street between Como Ave/Front Ave and TH 36
- Segment 16 – Old Highway 8 between 5th Avenue and County Road D
- Segment 18D – White Bear Avenue between County Road B and Frost Avenue
- Segment 19 – White Bear Avenue between Beam Avenue and Gervais Avenue
- Segment 21 – Cretin Avenue between University Avenue and Grand Avenue
- Segment 22 – Hamline Avenue between University Avenue and Grand Avenue
- Segment 23 – Minnehaha Avenue between Payne Avenue and 7th Street

Some segments that were well under capacity and were not expected to have major difficulties or impacts were not selected for further study since the County could complete the conversions with minimal effort.

4.1 Analysis Methodology and Criteria

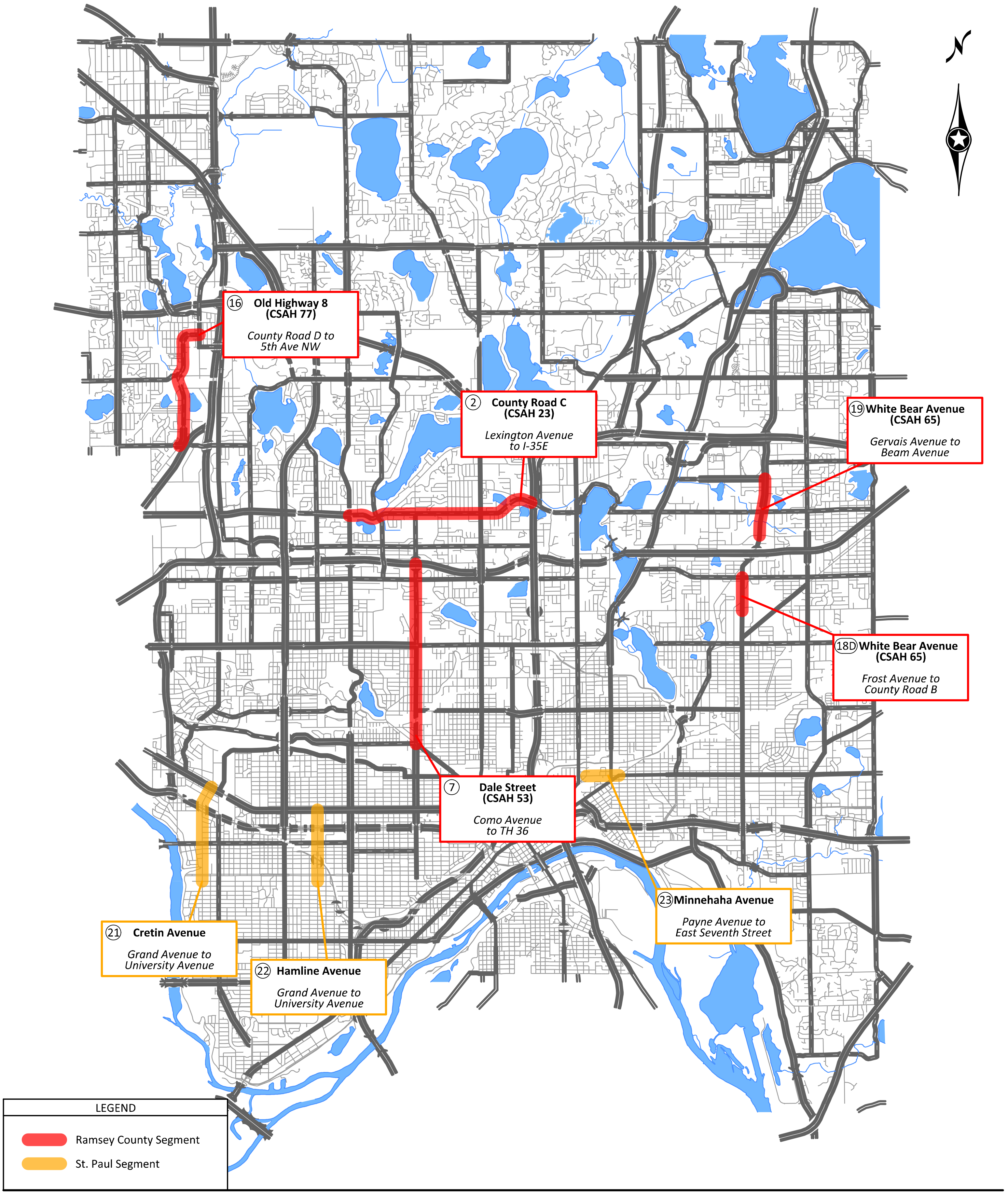
Detailed analysis included the development of lane reduction concept layout (or layouts), crash analysis, traffic operations analysis, parking analysis, and high-level cost estimate. The purpose of the detailed analysis was to obtain a better understanding of each segment and the impacts a lane reduction would have as well as develop a concept level layout of a lane reduction scenario.

Detailed analysis results for each segment including the following items can be found in **Appendices E-L**.

- Segment characteristics map
- Existing turning movement counts
- Parking analysis summary (if applicable)
- Evaluation summary matrix
- Concept design with operations analysis results
- Cost estimate

4.1.1 Concept Layout Development

A concept layout depicting a lane reduction concept (or concepts) was developed for each detailed analysis segment. The concepts were prepared on aerial photography to illustrate the potential lane configurations at intersections of each segment, including multi-modal amenities. Additionally, typical cross sections were shown for the lane reduction concept to show widths provided for travel lanes, on street parking, transit stops, turn lanes, etc. Results from the crash analysis and traffic operations analysis were shown on the maps. Modifications as a result of a lane reduction were identified for signalized intersections and noted on the concept layouts.



Four-Lane to Three-Lane Conversion Study

Figure 5
Segments Selected for Detailed Analysis

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4.1.2 Crash Analysis

Ramsey County provided Alliant with a crash history dataset containing crashes from 2016 to October 2019. A screening of crash prone locations was conducted along each of the detailed analysis segments. Locations were selected that had five or more crashes during the study period. A radius of 150 feet was used as a boundary to collect the number of crashes at each section. Once a list of locations was found, the data was cleaned. Crashes which were coded as being not on a roadway, in a parking lot, or on an incorrect street were removed from the analysis.

The AADT on the segment characteristics maps was used for the volume along the segment, whereas AADT volumes on the cross streets came from the MnDOT Traffic Mapping Application. The formulas for crash rates (CR) and critical crash rates (CCR) were obtained from Chapter 11 of the MnDOT Traffic Engineering Manual. Since the study period consisted of approximately four years and the MnDOT Intersection Green Sheets (2015) only contain values for three and five years of data, an average was calculated to form the statewide average for this project as shown in **Table** 3**3**. Low volume is defined as roadways with less than or equal to 15,000 vehicles per day, high volume is defined as roadways with greater than 15,000 vehicles per day, and low speed is defined as roadways with a speed limit less than or equal to 45 miles per hour. The crash severity index was also calculated using available crash data.

Table 3. Statewide Average Crash Rates

Intersection Type	Statewide Average
Low Volume, Low Speed (signalized)	0.52
High Volume, Low Speed (signalized)	0.71
Urban Thru/Stop (unsignalized)	0.19
All Way Stop (unsignalized)	0.35

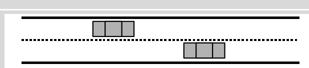
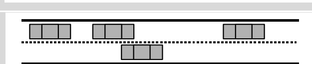
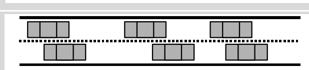
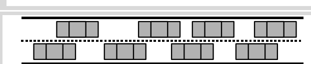
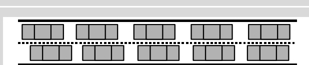
On each concept layout, each crash analysis location includes the top three crash types which are likely to be reduced by a four to three lane conversion (rear-end, head-on, angle, and sideswipe). If a pedestrian or bicyclist were involved in a crash and was not in the top three, this crash type was included over the third most. The intersection crash rate, critical crash rate, and severity index that were calculated were also included on the maps. A comparison was made between the existing average number of crashes per year and the projected average number of crashes per year. The average crashes per year was calculated by taking the total crashes at the intersection and dividing by the study period. The projected crashes per year was calculated by multiplying the existing average by the crash modification factor(s) (CMF) that best represent each applicable safety improvement.

CMF values were researched for 4 to 3 lane conversions on the CMF Clearinghouse website, which includes a library of CMFs with supporting documentation. From this repository, six research projects were found and provided crash reduction factors with one providing factors for specific roadway characteristics. These factors were used in the projected crash analysis and are documented in **Appendix M**.

4.1.3 Traffic Operations Analysis

A detailed peak hour traffic operations analysis was performed for the detailed analysis corridors. Each corridor was evaluated using micro-simulation traffic modeling to establish existing "baseline" conditions to compare to a potential "build" conversion alternative. The comparison was used to illustrate the potential operational impacts a conversion and loss of roadway travel lanes would have on a corridor. The traffic operations analysis was completed using Synchro/SimTraffic software with the key measures of effectiveness (MOE) evaluated being intersection delay and average queues. Micro-simulation was chosen since these detailed intersection MOEs are not able to be computed based on planning level thresholds identified in **Section 3**. Peak hour turning movement volumes were collected during January and February 2020 for all signalized intersections in each detailed analysis segment. In some concept alternatives analysis, signal timing (splits and offsets) were adjusted to account for the reduction in travel lanes. The term Level-of-Service (LOS), as taken from the HCM, refers to the ability of an intersection or arterial to process traffic volumes and is based on delay per vehicle. By definition, LOS A conditions represent high-quality operations and LOS F conditions represent very poor operations. The LOS criteria as defined by the HCM for both signalized intersections and urban arterials are shown in **Table 4**. Although traffic simulation models arrive at the average seconds of delay per vehicle differently than HCM procedures, the thresholds presented are still applicable. Intersections with minimal impacts to delay and queuing were not expected to have loss of mobility and thus favorable for conversion. However, intersections with excessive increased delays and queuing were expected to have a significant loss of mobility and thus less favorable for conversion.

Table 4. Level of Service Description

LOS	Description		Signalized Intersection	Un-Signalized Intersection
			Intersection Delay (Seconds / Vehicle)	Intersection Delay (Seconds / Vehicle)
A		**Free Flow.** Low volumes and no delays.	0 - 10	0 - 10
B		**Stable Flow.** Speeds restricted by travel conditions, minor delays.	>10 - 20	>10 - 15
C		**Stable Flow.** Speeds and maneuverability closely controlled due to higher volumes.	>20 - 35	>15 - 25
D		**Stable Flow.** Speeds considerably affected by change in operating conditions. High density traffic restricts maneuverability, volume near capacity.	>35 - 55	>25 - 35
E		**Unstable Flow.** Low speeds, considerable delay, volume at or slightly over capacity.	>55 - 80	>35 - 50
F		**Forced Flow.** Very low speeds, volumes exceed capacity, long delays with stop and go traffic.	> 80	> 50

Source: Highway Capacity Manual, 6th Edition (Published 2016), Transportation Research Board, Exhibit 18-1 for Signalized Intersections, Exhibit 19-8 for Un-Signalized Intersections, and Exhibit 16-3 for Urban Street Facilities.

4.1.4 Parking Analysis

Alliant conducted a parking analysis in January and February 2020 along segments which currently provide on-street parking. The parking analyses included counting parked vehicles at various periods throughout the day, evening, and late-night hours. Graphics were prepared to visualize the parking demand versus the estimated parking supply available.

4.1.5 Cost Estimate

Each detailed analysis segment concept design included a high-level cost estimate. This estimate included costs for mill and overlay pavement, signal revisions/replacement, and pavement markings, and flat percentages for traffic control, mobilization, and overall contingency. Implementation of lane reductions may have an impact to traffic signals and may require adjustments to detection methods and or signal heads and provide opportunity to adjust the overall signal phasing. Each traffic signal was examined, and unit costs were applied for relocation of signal heads, detection, and adjusting phasing.

Ramsey County provided preferences on pavement replacement including 2” mill and overlay and micro mill and overlay. Ramsey County provided costs for these operations for segments under their jurisdiction. White Bear Avenue (Segments 18D and 19) is programmed for reconstruction and full roadway replacement cost was not calculated for those segments. Ramsey County also provided approximate signal ages and signal replacement costs were used for signals past 75% of their expected life.

The City of St. Paul provided direction that all detailed analysis segments would get a 2” mill and overlay for the purposes of formulating a cost estimate. Additionally, the city provided a list of signalized intersections that signal replacement cost was used for the cost estimate.

It should be noted that the cost estimates were based on ideal situations and could change when detailed scoping is done to assess/identify project needs and develop a project plan.

4.1.6 Evaluation Summary Matrix

Sub-segments of each detailed analysis segment were analyzed based on factors mentioned in **Sections 4.1.2** through **4.1.5**. Results, including key findings, favorability, and conclusions, were summarized in a matrix by segment. The conclusion results were categorized in terms of benefits, impacts, or feasibility.

The key factors were:

- **Crash Patterns.** When a roadway is converted from 4 to 3 lanes, the number of conflict points is reduced and a reduction in crashes can be expected. Number of crashes, types of crashes, crash rates, and crash severities were all analyzed. Crash modification factors (CMFs) were also found that best fit the intersection environment and used to project future number of crashes.
- **Curbside Uses.** It is important to understand all of the roadway users apart from motorists driving along the corridor. Some corridors have on-street parking, some have transit, and some have existing or planned bicycle facilities. The available roadway width (discussed in more detail in the final key factor below) informs potential options for these uses and whether or not they can be accommodated on both sides of the road, on one side, or not at

all. It should be noted that if a segment moves towards implementation, close coordination with Metro Transit will take place to accommodate transit operation needs.

- **Roadway Function/Mobility.** The results of the Synchro/SimTraffic analysis were used to inform the level of service of the roadway under a new configuration. Acceptable LOS can be different based on the intended function/desired mobility of the roadway.
- **Average Daily Traffic (ADT).** Generally, as a 3-lane roadway approaches 17,000 vehicles per day, it is nearing capacity. Some roadways can handle higher volumes if there are many access points and slower speeds are desired.
- **Peak Hour Traffic Volumes.** The theoretical capacity of a 3-lane roadway is roughly 750 vehicles per hour per travel lane. As with daily volumes, some roadways can handle higher peak hour volumes.
- **Traffic Volume Directional Distribution.** Directionality of a roadway can also have an impact on the feasibility and benefit of a 3-lane roadway. Roadways with volumes that are unbalanced (weighted more heavily toward one direction) do not operate as well under a 3-lane scenario as roadways with balanced volumes do.
- **Motor Vehicle Speeds.** Previous studies have shown that 4 to 3 lane conversions can reduce speeds along roadways. A standard measure of prevailing speed is the 85th percentile speed. This data was collected by StreetLight Data and was compared to the posted speed limit on the segment.
- **Access Points and Turning Traffic Patterns.** Roads with high number of mid-block access points can greatly benefit from a 4 to3 lane conversion by removing turning vehicles from a through travel lane. In some cases, such as offset driveways or multiple high-volume access points, a two-way center turn lane could be detrimental.
- **Roadway Width.** If a roadway must accommodate curbside uses such as on-street parking, loading zones, and transit stops, a wider road width is required than a road with no curbside uses. If a road is 39 feet wide or less, no curbside uses can be accommodated with a 3-lane configuration (assuming a minimum of two 11’ travel lanes, 10’ two-way left turn lane or median, and 8’ parking lane). If a road is at least 48 feet wide it can accommodate curbside uses on both sides of the road. A roadway with a width in between these values could accommodate curbside uses on one side.

4.2 Detailed Analysis Results

A summary of the detailed analysis results are in the following section and are shown in **Table 5**. Detailed analysis results for each segment including the following items can be found in **Appendices E-L**.

- Segment characteristics map
- Existing turning movement counts
- Parking analysis summary (if applicable)
- Evaluation summary matrix
- Concept design with operations analysis results
- Cost estimate

Table 5: Detailed Analysis Summary

	Road Segment	Extents	Curbside Use Impact	Traffic Operations Impact	Other Considerations	Concept Design Scope
2A	County Road C (CSAH 23)	Lexington Ave to Victoria St	Low	Low	Capacity analysis needed at Victoria (split phasing, long queues). No Curbside Uses. Entering traffic on western end is 4 lane divided. 1 signal.	2-Lane Restripe+Sig Mods
2B		Victoria St to Rice St	Moderate	Low	Capacity analysis needed at Victoria and Rice (split phasing, long queues). High access density. 2 signals.	3-Lane Restripe+Sig Mods
2C		Rice St to RR Bridge	Low	Low	High access density with offset streets. 1 signal. Low volumes.	3-Lane Restripe+Sig Replace
2D		RR Bridge to I-35E	Moderate	High	Entering traffic on eastern end is 2 lane with shoulders. High access density. 2 signals - very closely spaced.	3-Lane Restripe+Sig Mods
7A	Dale Street (CSAH 53)	Como Ave to Larpenteur Ave	High	High	4-lane divided on southern end. 5 signals. Low-medium access density on most blocks, some blocks high density.	3-Lane M&O+Sig Replace+Sig Mods
7B		Larpenteur Ave to CR B	Moderate	Moderate	2 signals. Medium access density, offset streets.	3-Lane M&O+Sig Replace+Sig Mods
7C		CR B to TH 36	Low	Low	2-lane with shoulders on northern end. 3 signals (if you count both TH 36 signals). High access density.	3-Lane M&O+Sig Mods
16A	Old Highway 8 (CSAH 77)	CR D to 5th St	Low	Low	Traffic entering on south side is 3-lane. High access density. 1 signal. Segment currently may have detour traffic from MnPASS (ADT of unknown)	3-Lane Restripe+Sig Mods
16B		5th St to RR Crossing	Moderate	Low	High access density. No signals. Segment currently has detour traffic from MnPASS (ADT of 15,700)	3-Lane Restripe
16C		RR Crossing to 8th Ave	Moderate	Low	Utility pole company on corridor - large timber trucks. Ped crossing difficulty at DQ at trailer park. High access density. 1 signal. Segment currently has detour traffic from MnPASS (ADT of 14,500)	3-Lane Restripe+Sig Mods
16D		8th Ave to 5th Ave	Low	Low	Traffic entering on north/east side is 4-lane with turn lanes. Queueing on bridge. Bridge needs replacement. High access density. 1 signal. Segment currently has detour traffic from MnPASS (ADT of 7,800)	3-Lane Restripe
18D	White Bear Avenue (CSAH 65)	Frost Ave to CR B	Moderate	High	2 signals.	2-Lane NB/1-Lane SB Restripe+Sig Replace+Sig Mod
19	White Bear Avenue (CSAH 65)	Gervais Avenue to Beam Avenue	Moderate	Moderate	Basically existing 5-lane. Entering traffic on north is 6-lane, on south is 4-lane with turn lanes. 3 signals. Access density is variable - high in some spots.	3-Lane Reconstruct+Sig Replace+Sig Mod
21A	Cretin Avenue	Grand Avenue to Marshall Avenue	High	Moderate	Traffic entering on southern end is 4-lane with left turn lanes. 3 signals.	3 Lane Restripe+Sig Mods
21B		Marshall Avenue to I-94	High	**Extremely High**	2 signals. No sidewalk along golf course, all ped crossings are bus-related. Motorists come across Marshall from Minneapolis and use this corridor to get to 94.	3 Lane Restripe+Sig Mods
21C		I-94 to University Ave	Moderate	Low	Traffic entering on northern end is 4-lane with left turn lanes. 3 signals.	3 Lane Restripe+Sig Mods
22A	Hamline Avenue	Grand Avenue to Ayd Mill Rd	Moderate	Low	Entering traffic on both sides is 2-lane. Potential parking issues (off-peak parking permitted). 3 closely spaced signals	3 Lane Restripe+Sig Mods
22B		Ayd Mill Rd to I-94	Moderate	High	3 closely spaced signals. Large bridge over Ayd Mill	3 Lane Restripe+Sig Mods
22C		I-94 to University Ave	Moderate	Low	Entering traffic on north side is 2-lane. North end would be expected to have operations issues, capacity analysis may be needed. 4 closely spaced signals.	3 Lane Restripe+Sig Mods
23	Minnehaha Avenue	Payne Avenue to East Seventh Street	Moderate	Low	Entering traffic on both sides is 2-lane. 3 signals. Low access density.	2 Lane M&O+Sig Mods

Concept Design Implementation Scope Legend

Restripe
Mill & Overlay
Reconstruction

4.2.1 Segment 2 – County Road C between Lexington Avenue and I-35E

This segment is located in Little Canada and Roseville. The Concept Design Alternative 1 was a traditional 3-lane segment with a two way center left turn lane and turn lanes at key high volume locations and a 2-lane segment west of Victoria Street. The Concept Design Alternative 2 was similar to Alternative 1 but did not reduce lanes east of the Little Canada Road/Lakeshore Avenue intersection. The roadway west of the Little Canada Road/Lakeshore Avenue has AADT's that are generally within 2 and 3 lane road capacities but peak hour delays and queues would be expected at the Victoria Street intersection. A potential roundabout was discussed at this location and modeling indicates it would improve intersection operations in a lane reduction scenario. Between Lexington Avenue and Victoria Street there are currently no curbside uses but bike lanes are planned for the future. This segment could be reduced to a 2-lane facility with no traffic operations impact. There is transit on this portion of the corridor and bike lanes are planned. Peak hour delays and queues would be expected east of the Little Canada Road/Lakeshore Avenue intersection including the I-35E interchange.

4.2.2 Segment 7 – Dale Street between Como Ave/Front Ave and TH 36

This segment is located in St. Paul and Roseville. The existing Como Avenue/Front Avenue intersection operates at or above capacity and a lane reduction compounds the situation. Alternatives were included for this intersection for starting the conversion at the intersection as well as starting the conversion approximately 500 feet north of the intersection. A conversion would allow the removal of split phasing at the Dale Street and County Road B intersection which would improve capacity. The concept design was a traditional 3-lane segment with a two way center left turn lane and turn lanes at key high volume locations. Dale Street is a 2-lane roadway just north of TH 36.

4.2.3 Segment 16 – Old Highway 8 between 5th Avenue and County Road D

This segment is located in New Brighton. The concept design was a traditional 3-lane segment with a two way center left turn lane. The corridor has a high number of driveway crashes and rear end crashes which could be mitigated with a 3-lane roadway. AADTs are below a 3-lane roadway capacity and overall minimal impact to roadway function/mobility would be expected with a lane reduction.

The intersection at Old Highway 8/1st Street was an all-way stop-controlled intersection prior to the installation of a construction temporary traffic signal installed as part of the I-35W MnPass project in early 2019. If the intersection returns to an all way stop, a 3 lane conversion would be expected to operate at LOS E during the PM Peak with moderate queueing. While the intersection does not meet MnMUTCD signal warrants under a 3 lane conversion scenario, if signalized, it would be expected to operate at LOS B or better during the PM Peak, with minimal increase in average queue lengths along Old Highway 8.

The northbound Long Lake Road merge with Old Highway 8 on the southern end of the corridor poses a unique lane configuration challenge with a lane reduction on Old Highway 8 north of County Road D. There are several options that can be considered for this merge area including leaving the entire merge area as-is, and simply reduce to 1 northbound travel lane north of Campus Drive.

4.2.4 Segment 18D – White Bear Avenue between County Road B and Frost Avenue

This segment is located in Maplewood. The Concept Design Alternative 1 included a traditional 3 lane roadway with a two way center left turn lane. A variation Alternative 2 was developed with 2 northbound lanes, a two way center left turn lane, and a southbound lane. Although AADTs and peak hour volumes are quite high and intersection capacity will be pushed to the limit during peak hours at White Bear Avenue and County Road B, there is a substantial safety benefit expected for driveway access on the east side of White Bear and will result in reduced speeds and crashes. There is one transit route on the corridor but delays created by buses stopping in a travel lane will be minimal due to long headways.

4.2.5 Segment 19 – White Bear Avenue between Beam Avenue and Gervais Avenue

This segment is located in Maplewood. The Concept Design included a traditional 3 lane roadway with a two way center left turn lane. A lane reduction of this segment would have moderate impacts to roadway function and mobility. Once again, AADTs and peak hour volumes are quite high, but overall safety would be expected to increase through reduced crashes and speeds. Curbside uses could be accommodated on both sides of the road with a 3-lane configuration. There are three transit routes on the corridor sometimes with headways as low as 5 minutes. A 3-lane alternative could allow for buses to stop out of the travel lane or the addition of parking or bike facilities.

4.2.6 Segment 21 – Cretin Avenue between University Avenue and Grand Avenue

This segment is located in St. Paul. The base Concept Design Alterative 1 included a traditional 3 lane roadway with a two way center left turn lane. The peak hour traffic operations analysis results indicated significant operational impacts between I-94 and Marshall Avenue. A variation Alternative 1A was developed based off Alternative 1 and the segment between I-94 and Marshall Avenue was adjusted to one southbound travel lane, and two way center left turn lane, and two northbound travel lanes because all access along this segment is on the east side of Cretin. Predictably, the peak hour traffic operations results continued to indicate significant operational impacts between I-94 and Marshall Avenue. A final Alternative 2 was developed which include a traditional 3 lane roadway north of I-94 and south of Marshall Avenue. The peak hour traffic operations results indicated more favorable operations but the Cretin Avenue and Marshall intersection would still operate above capacity. If a conversion were to take place, there would be an opportunity to extend it north of University Avenue. It was also noted that the segment between I-94 and Marshall Avenue does not have pedestrian accommodations on the west side and could benefit from accommodations and enhanced pedestrian crossings to access transit stops. The southern end of this segment has peak hour restricted on-street parking and was observed to be heavily used. During off peak times, several areas along this corridor operate acceptably as 2-lane roadway.

4.2.7 Segment 22 – Hamline Avenue between University Avenue and Grand Avenue

This segment is in St. Paul. The base Concept Design included a traditional 3 lane roadway with a two-way center left turn lane along the majority of the segment. At Summit Avenue, the side by side left turn lanes need to remain due to the wide median along Summit. The peak hour traffic operations analysis results indicated moderate to significant impacts between I-94 and Ashland Avenue/Ayd Mill Road. This segment is diverse with residential land uses at the south end, Concordia University and I-94 in the middle, and retail/commercial uses at the north end.

4.2.8 Segment 23 – Minnehaha Avenue between Payne Avenue and West 7th Street

This Segment is in St. Paul. The base Concept Design Alternative 1 was a 2-lane roadway. A variation Alterative 2 was developed based off Alterative 1 and has turn lanes provided at each intersection. A lane reduction of this segment, for either Alternative 1 or 2, would have a very low impact to roadway function and mobility. The vacated curb lanes on both sides of the street could accommodate the limited existing on street parking.

5.0 Prioritized Implementation Plan

A prioritized implementation plan was developed for all study segments and was split into segments under Ramsey County jurisdiction and segments under St. Paul jurisdiction.

The Ramsey County segments were initially sorted by ease of implementation based on either assumed lane reduction scope from the feasibility analysis or concept designs from the detailed analysis. Segments requiring a simple restripe ranked higher on the list than segments that may need a mill and overlay and full reconstruction projects ranking at the bottom. Mill and overlay and reconstruction projects will likely require capital improvement funding that may take several years to program and implement. The ranking within each category utilized key information collected or calculated over the course of the study including pavement condition index, curbside use impacts related to on-street parking and transit stops, traffic operations impact related to either actual intersection capacity analysis from the detailed analysis or estimated capacity from the feasibility analysis, and the segments overall benefit score from the feasibility screen. Segments ranked higher in priority generally had lower curbside and traffic operations impacts and higher estimated benefit scores. The Ramsey County segment implementation ranking results are shown in **Table 6.**

The St. Paul segments were ranked following a similar process as the Ramsey County segments. However, the Minnehaha Avenue segment likely needing a mill and overlay was ranked the highest over the Cretin Avenue and Hamline Avenue segments because of the relatively low cost and low curbside and operational impacts compared to the others. The St. Paul segment implementation ranking results are shown in **Table 7**.

Detailed prioritization ranking analysis can be found in **Appendix N**.

Table 6. Ramsey County Segments Implementation Ranking

Ease of Implementation Priority Ranking	Segment Number	Road Segment
Scope: Restripe		
1	10	**Lydia Avenue (CSAH 19)**
2	13	**Maryland Avenue (CSAH 31)**
3	12	**Maryland Avenue (CSAH 31)**
4	18	**White Bear Avenue (CSAH 65)**
5	5	**County Road F/10th Street NW (CSAH 12/45)**
6	8	**Fairview Avenue (CSAH 48)**
7	11	**Marshall Avenue (CSAH 35)**
8	14	**McKnight Road (CSAH 68)**
9	3	**County Road D (CSAH 19)**
10	1	**County Road B2 (CSAH 24 and 78)**
11	16	**Old Highway 8 (CSAH 77)**
12	4	**County Road E (CSAH 15)**
13	17	**Silver Lake Road (CSAH 44)**
14	2	**County Road C (CSAH 23)**
15	9	**Lexington Avenue (CSAH 51)**
Scope: Mill and Overlay		
16	6	**Dale Street (CSAH 53)**
17	7	**Dale Street (CSAH 53)**
Scope: Reconstruct		
18	19	**White Bear Avenue (CSAH 65)**
19	20	**White Bear Avenue (CSAH 65)**

Table 7. St. Paul Segments Implementation Ranking

Ease of Implementation Priority Ranking	Segment Number	Road Segment
Scope: Mill and Overlay		
1	23	**Minnehaha Avenue**
Scope: Restripe		
2	22	**Hamline Avenue**
3	21	**Cretin Avenue**

6.0 Stakeholder Engagement

A Technical Advisory Committee (TAC) was involved throughout the study process. The TAC consisted of representatives from Ramsey County, the City of St. Paul, the City of Maplewood, the City of New Brighton, and the City of Roseville. The TAC met four times over the course of the project to review findings and provide input on next steps. TAC meeting minutes can be found in **Appendix O**.

Once detailed analysis was completed for the selected segments, Alliant and County staff met with the City of St. Paul individually to share information and preliminary detailed analysis results for City specific segments 7, 21, 22, and 23. Alliant and County staff also met with MnDOT to discuss preliminary results on segments that included or were near state roadways that included segments 2, 7, 16, 21, and 22. Meeting minutes from these two meetings can be found in **Appendix P**.

Finally, detailed analysis results were shared individually with the cities of New Brighton, Maplewood, Little Canada, and Roseville for segments 2, 7, 16, 18D, and 19.

Appendix A:
Literature Search Sources

Appendix B:
Segment Characteristics Maps

Appendix C:
Feasibility Screening Results

Appendix D:
Benefit Screening Results

Appendix E:
Segment 2 Detailed Analysis Results

Appendix F:
Segment 7 Detailed Analysis Results

Appendix G:
Segment 16 Detailed Analysis Results

Appendix H:
Segment 18D Detailed Analysis Results

Appendix I:
Segment 19 Detailed Analysis Results

Appendix J:
Segment 21 Detailed Analysis Results

Appendix K:
Segment 22 Detailed Analysis Results

Appendix L:
Segment 23 Detailed Analysis Results

Appendix M:
Crash Modification Factors

Appendix N:
Prioritization Ranking Analysis

Appendix O:
Technical Advisory Committee Meeting Minutes

Appendix P:
Stakeholder Outreach Meeting Minutes