

3. Existing Conditions & Analysis

This chapter contains descriptions and analysis of a variety of existing conditions found throughout the Highway 23 / Grand Avenue corridor. Issues related to safety, operations, and level of service (LOS) were looked at with respect to the different modes of transportation and the impacts of potential changes in land use patterns and future traffic volumes.

Conditions were assessed both in terms of the entire 5-mile corridor from Becks Road to I-35 and the six individual context zones identified within that corridor (as identified in Section 1, pages 2-5). The purpose of proceeding in this manner was not only to seek ways in which the corridor might better serve its various users, but also help to identify very specific, localized issues and to perhaps develop recommendations that can address those unique issues in a targeted and cost-effective manner. The next 34 pages, therefore, address issues and opportunities in terms of the entire highway corridor, while pages 37 - 69 identify and address issues that are specific to the six distinct context zones.

Land Use and Traffic Patterns

Land use patterns change significantly from one end of the Highway 23 corridor to the other. This is the primary reason for segmenting the corridor into six distinct context zones: conditions and traffic patterns vary accordingly. As one travels the highway from southwest (Becks Rd) to northeast (I-35), the corridor transitions from a rural to an urban environment, and land uses and traffic movements change in number and density (Figure 3.1). This translates into different concerns throughout the corridor. Conditions related to the speed of traffic, for



Image source: Google Maps (2013)

Figure 3.1 | Urban section of Highway 23

The area around the five-legged intersection of Raleigh Avenue represents an urban section of the Highway 23 / Grand Avenue corridor where issues related to turning movements at acute-angle intersections are more prevalent than in the corridor's more rural sections.



Figure 3.2 | Traffic on Highway 23 / Grand Avenue

The wide roadway, limited signalization, and heavy traffic patterns found on Highway 23 have the potential to create barriers to access, especially for non-motorized users trying to cross the highway.

instance, are more significant in the rural sections to the southwest, while conditions related to turning movements at acute-angle intersections are an issue at the other end of the corridor.

There is a mix of residential, commercial, and industrial activities throughout the corridor, which produce varying traffic patterns. The corridor experiences the typical AM and PM hours of peak travel, but also becomes substantially busier as the day progresses. There are also recreational uses, such as the Lake Superior Zoo and the new Spirit Mountain Chalet that generate higher levels of traffic during certain seasons or events. At these times, different issues related to traffic operations and parking along the corridor can emerge.

In addition, Highway 23 serves as an important regional travel corridor for both daily commuters and heavy trucks hauling freight. As such, the route has been designed as a 4-lane highway to facilitate these movements in addition to local access. But the density of land use and traffic throughout much of the corridor is too low to warrant traffic signalization. This translates into a land use pattern of its own, one which impedes non-motorized movements across the roadway and in a sense separates uses on the northern side of the corridor from activities on the southern side (Figure 3.2).

Local Access and Regional Through Routes

As explained in Section 1, Highway 23 is the only thru-route connecting the neighborhoods in far West Duluth. Even though I-35 lies just to the north, there are no connector routes between it and the neighborhoods to the south. Therefore, the residents in those neighborhoods have only one option, Highway 23, to access I-35 or other destinations in the metro area. Furthermore, anyone wishing to pass through the area is likewise dependent on the highway, as the alternatives (I-35 or through the City of

Superior) are several miles longer. This is apparent in Map 3.1 on the following page, which shows the regional through routes in green.

In addition, Highway 23 is not weight-restricted as the interstate and the Oliver Bridge over the St. Louis River are. So, the highway is also a critical thru-route for heavy freight movements. Map 3.1 (page 24) shows the weight-restricted routes in red, and it is again apparent that Highway 23 is the sole alternative. The highway is also in close proximity to a regional rail corridor, which creates opportunities for the intermodal transfer of goods. All of this underscores the importance of Highway 23 as a principal arterial and the need for MnDOT to protect its capacity into the future.

However, the highway is equally as important for local access as it is for through movements. It serves six neighborhoods (Map 3.2, page 25), each with varying degrees of access to the highway and surrounding facilities. Moving forward, it will be just as important to ensure good access to the residences and business along the highway as it will be to ensure capacity.

The area around the Highway 23 / Grand Avenue corridor is also graced with a number of local and regional trails, most of which come into close proximity to the highway. The Munger Trail, DWP Trail, Western Waterfront Trail, and future Cross City Trail are all important connections for non-motorized commuter and/or recreational travel. However, the connections between these facilities, the highway, and the neighborhoods are limited and thus represent a poorly integrated transportation system.

Traffic Volumes

Traffic volumes differ significantly from one end of the Highway 23 corridor to the other. Near Becks Road to the southeast, daily traffic is around 8,400 vehicles per day. Yet, as one moves eastward along the

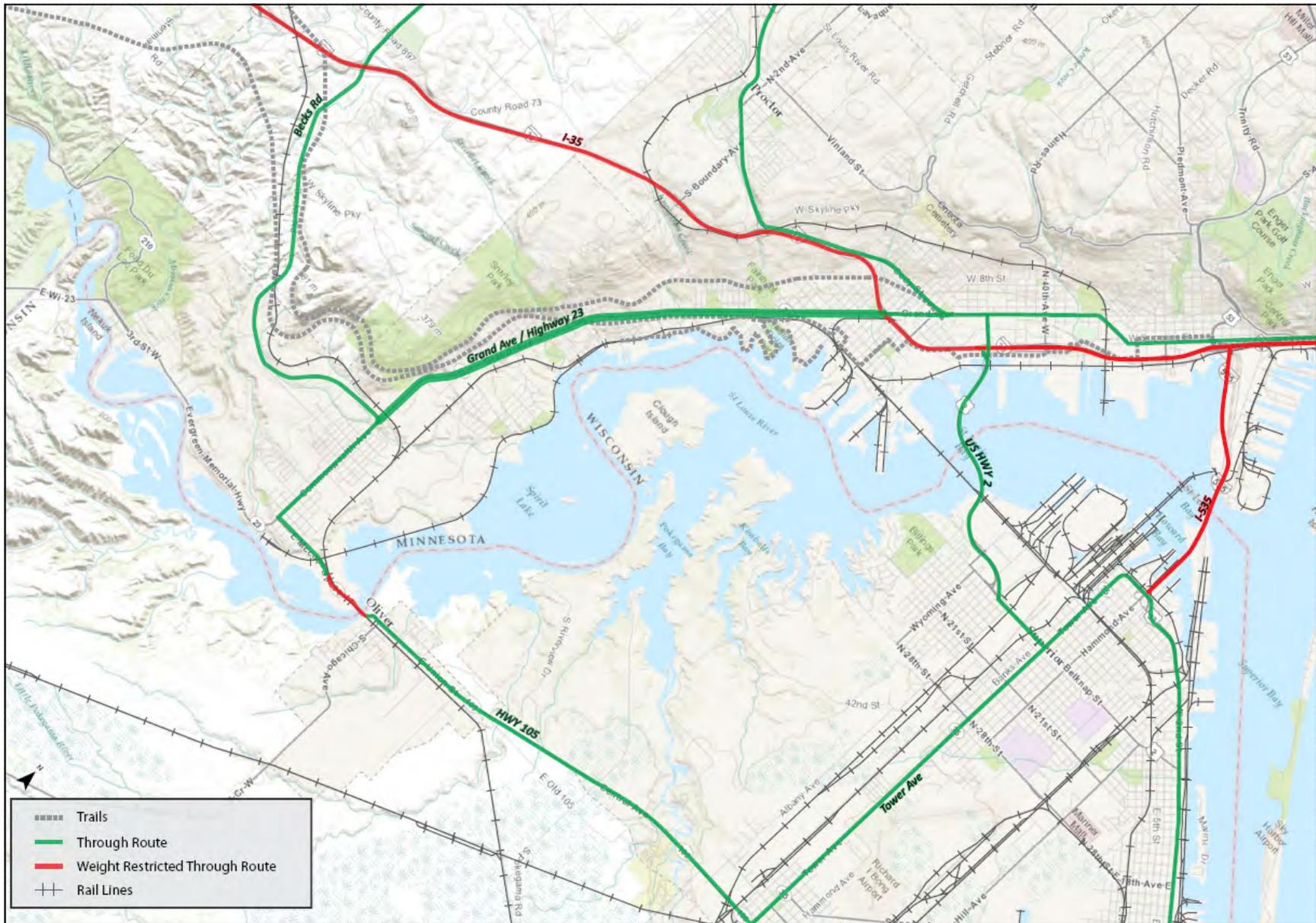


Image source: Google Maps (2013)

Figure 3.3 | Rail crossing and trail head at Pulaski Street

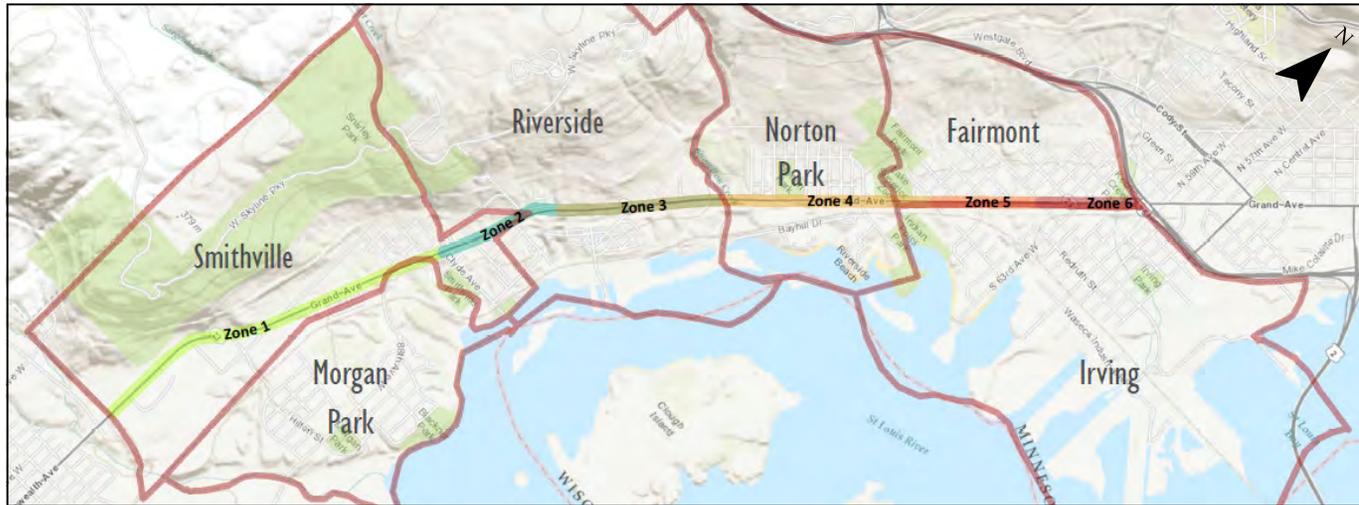
Rail and trail corridors exist in close proximity to Highway 23, creating opportunities for intermodal connections.

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Map 3.1 | Alternative through routes and regional trails

Highway 23 / Grand Avenue is the most direct arterial route that connects land uses southwest of the I-35 interchange. It is also the only route without weight-restrictions for heavy-haul truck trips. Intermodal opportunities also exist between the highway and area railways and trails systems.



Map 3.2

Highway 23 context zones & West Duluth neighborhoods

This plan identifies six distinct zones where the land use context changes along the roadway. These zones correspond roughly to the locations of the different neighborhoods along the corridor. Data collection and analysis were done according to these zones.

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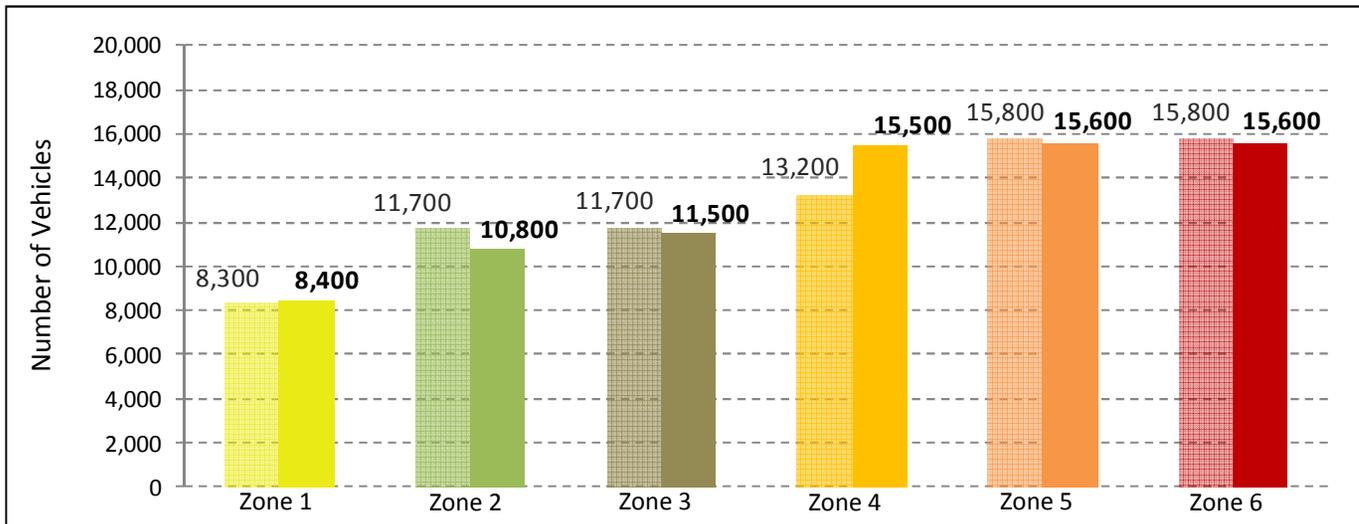


Figure 3.4

Comparison of average annual Daily Traffic: 2002 to 2011

Traffic volumes are heavier in the context zones closest to I-35. There has been a slight decrease in daily traffic over the past decade, with the exception of Zone 4, a residential area which has seen traffic increase by more than 2,000 cars per day.

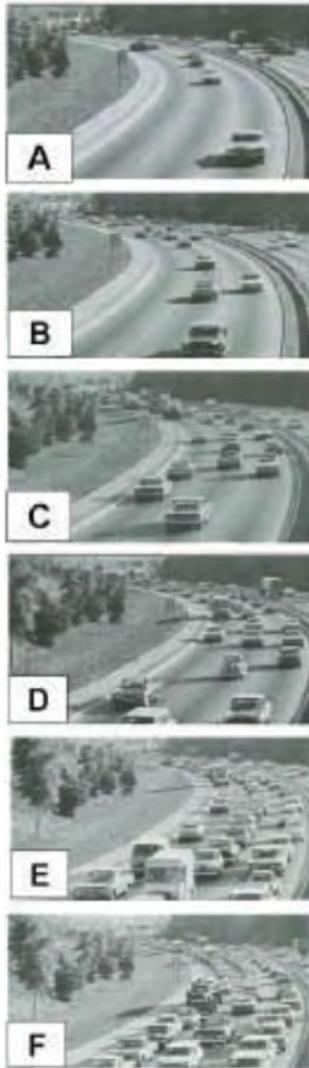


Figure 3.5 | Vehicle level of service (LOS)

LOS is a qualitative statement about the road's operation (A-F), but is based more quantitatively on the measure of number of vehicles present compared to a road's capacity.

highway, volumes continue to increase until in the segments nearest I-35 (zones 5 and 6), traffic is nearly doubled at 15,600 vehicles per day.

Vehicle counts taken since the year 2002 show that traffic has decreased slightly over much of the corridor. This is a pattern consistent with those at the state and national level that show a general flattening in the amount of annual vehicle miles traveled (VMT). The mid-section of the Highway 23 corridor, however, stands out as an exception to this trend. As Figure 3.4 on page 25 shows, traffic has increased in Zone 4 by more than 2,000 vehicles a day over the past decade. This change corresponds with the fact that Zone 4 is also the only zone in the corridor that received new housing developments during the same period.

Turning movement counts that were done at 75th Avenue W in May 2012 showed the peak hour of traffic in Zone 4 to be between 4:30 PM and 5:30 PM. Traffic was 1,470 vehicles (9% of daily traffic), with about 400 vehicles during the most congested 15 minutes within that hour. According to the 2010 Highway Capacity Manual (HCM), at a free-flow speed of 45 mph, this volume of traffic represents a vehicle/capacity (V/C) ratio of 0.21, which equates to a level of service (LOS) of "B" and represents a state of virtually no congestion.

Turning movements that were done at the intersection of Highway 23 and Raleigh Street in Zone 6 in April 2013 showed a slightly higher peak hour volume of 1,556 vehicles (10% of daily traffic), with a peak 15-minute volume of 415 vehicles. This still represents a LOS "B", and indicates there is more than enough capacity to meet current traffic demands.

Despite a trend towards flattening VMT, future development is expected along the Highway 23 corridor. The impacts of this growth on the traffic capacity of the roadway are projected to be significant but still remain better than an LOS D (see Figure 3.5). During this study, the traffic

impacts of a build-out scenario were assessed with regards to the six individual context zones. Those impacts are discussed in more detail starting on page 37.

Heavy Truck Volumes

Heavy Commercial Truck AADT (HCAADT) data published by MnDOT shows that daily truck volumes make up about 4% of the total daily traffic on Highway 23. An average volume of 340 trucks per day were reported in Zone 1 in 2011, while an average of 640 trucks per day were reported in Zones 4, 5, and 6.

Heavy trucks were also counted during the April 2012 vehicle counts at Raleigh Street. They represented 2% of traffic at mid-day, but less than 0.05% of traffic during the PM peak. This suggests that there are times throughout the day when heavy trucks represent significantly more than 4% of traffic in the corridor.

It was beyond the resources of this study effort to collect data for a more detailed analysis of daily truck patterns throughout the corridor, but further study in this area may be warranted.

Transit Service & Demand

Highway 23 belongs to the Duluth Transit Authority’s (DTA) west mainline, which the DTA has identified as the transit corridor that generates the most ridership in the Duluth-Superior metro area. The corridor is actually served by three different bus routes, the characteristics of which are summarized in Table 3.1.

Route No. 1 runs approximately every half-hour between 5:00 AM and Midnight between downtown Duluth to the Lake Superior Zoo, where it turns around at 71st Ave W. Route No. 3 also runs between downtown and the zoo, but does so on more of an hourly basis. Route No. 2, on the other



Figure 3.6 | Heavy truck traffic

Heavy trucks make up approximately 4% of the daily traffic in the Highway 23 / Grand Avenue corridor. But there are hours during the mid-day, when trucks represent a significantly greater percentage of the traffic.

| Route Attribute | I-35 to Zoo (Routes 1 & 3 both ways) | Zoo to Gary/ NewDuluth (Route 2 both ways) |
|--|--------------------------------------|--|
| <i>Avg number of bus trips per day</i> | 66 westbound 68 eastbound | 28 westbound 30 eastbound |
| <i>Avg bus headway (minutes)</i> | 18 minutes | 42 minutes |
| <i>Avg bus occupancy</i> | 48% capacity | 28% capacity |

Table 3.1 | Characteristics of Highway 23 transit service

Bus service is more frequent and more heavily utilized east of the transit turnaround at the Lake Superior Zoo.



Figure 3.7 | DTA bus service along Highway 23

The Highway 23 / Grand Avenue corridor represents one of Duluth Transit Authority's (DTA) most utilized bus routes.

hand, travels about eight miles further beyond the zoo to Highway 210 in Fond Du Lac and travels the Highway 23 / Grand Avenue corridor approximately every hour. Together, these three routes create a pattern of transit frequency in the corridor that is reflected in Map 3.3 on page 29, in which a bus could be boarded every 15-18 minutes in the 1-mile stretch between the zoo and I-35, while the rest of the corridor experiences a bus roughly every 45 minutes to an hour.

The pattern of transit frequency appears to complement the patterns of residential density (depicted in black on maps 3.3 and 3.4) that are found in the neighborhoods along the highway corridor. With that said, even though buses run less frequently southwest of the zoo, there are still bus stops in that part of the corridor that produce daily ridership levels comparable to the stops northeast of the zoo that get have more frequent transit service. This is shown in Map 3.4 on page 29 and begs the question as to whether transit service under its current configuration is sufficiently meeting demand within that section of the corridor. Although the MIC received no comments to that effect received from the stakeholder engagement during this study, it should be noted that transit riders were not specifically surveyed along the corridor, and thus some further assessment of this on the part of the DTA may be warranted.

A number of comments were received, however, during the stakeholder outreach efforts for this study that highlighted challenges with respect to accessing a number of the bus stops in the corridor. People reported experiencing or witnessing difficulties in accessing buses either because of poor sidewalk connections or because of the challenge of crossing the highway at busier times. Specific locations that were identified through stakeholder engagement are addressed for each of the context zones discussed in Section 2 of this study (pages 15 -17).

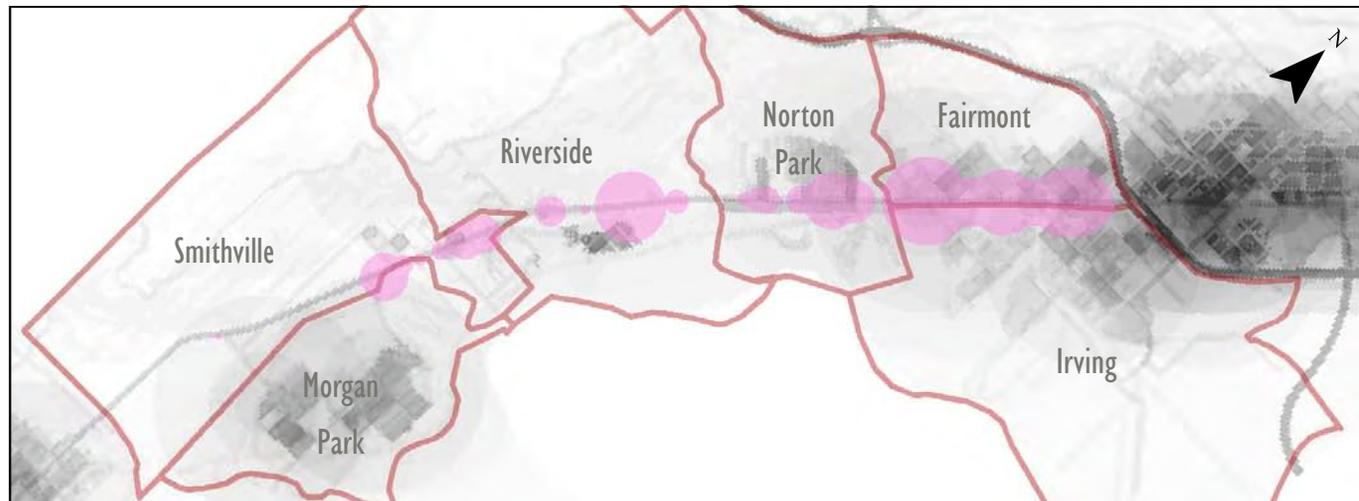
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1. Average frequency for service provided between 4:30 AM and 12:00 AM.

Map 3.3 | Transit frequency

The DTA runs three routes along Highway 23 south of I-35. The section of the highway north of the turnaround point at the zoo (71st Ave W) has buses running approximately every 18 minutes, while the majority of the corridor has buses passing through every 45 -minutes, on average.



Map 3.4

Daily transit boardings & alightings

The majority of transit ridership along Highway 23 comes from the more densely populated area near I-35 (area shown in black). Some transit stops further south, however, also generate large numbers of riders.



Figure 3.8 | Posted speed limit in Zone 1

The more rural sections of the Highway 23 corridor are posted for a speed limit of 45 mph. The average free-flow speed in these areas, however, is believed to be above 50 mph, due largely to the wide and normally non-congested roadway.

Traffic Speeds

As with traffic volume, the speed of traffic also differs throughout the Highway 23 corridor, depending on the location and time of day. Some of this is due to the fact that different sections of the highway have different speed limits. As Map 3.5 shows on page 31, the southern two-thirds of the corridor have a posted speed limit of 45 mph, while the 2-mile section north of the Riverside neighborhood is posted for 35 mph. It can also be seen in the map that the lower speed limit corresponds with the portion of the corridor with greater residential densities (shown in black) along the highway. In the portion of the corridor posted for 45 mph, the concentrations of residential uses are located away from the highway.

During the mid-day and PM peak hours of travel, the free-flow of traffic becomes more variable the closer one gets to I-35. This is because of a combination of the higher traffic volumes, greater density of driveways, more turning vehicles, and traffic signals at 71st Ave W and Raleigh St. However, outside of these more congested times, the free flow of traffic remains fairly consistent' and this is in large part because of the excess capacity offered by the existing four lanes.

MnDOT District 1 has reported that past speed inventories have shown average free flow speeds of around 52 mph in the section of Highway 23 that is posted for 45 mph and average speeds of 48 mph in the segment posted for 35 mph. This matches observations made the MIC staff while driving the corridor during this study effort and is consistent with the range of LOS - LOS "A" (non-peak) to LOS "B" (peak) - that is estimated to presently exist, based on the current AADT information.

Input gathered through the various stakeholder outreach efforts indicates that users of the highway have few concerns about the efficiency of traffic operations along the corridor. In fact, many said that they



Map 3.5

Posted speeds on Highway 23

The highway is posted for 35 mph in the more densely populated, urban half of the corridor. The speed limit increases to 45 mph west of the neighborhood of Norton Park.

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appreciated the quickness with which they could travel through the corridor and would not want to see any reductions made to the posted speed limits or the number of lanes.

However, there was also a sizable contingency of stakeholders that voiced concerns about the impact that current speeds have on the safety of the corridor. The perspective of many was that current speeds are too fast; they are leading to more crashes and making the corridor unsafe for pedestrians and cyclists who wish to cross or travel along the highway. This concern is addressed with the following discussion of trends found in the historical crash data for the corridor, but is also spoken to in the discussion on pages 36 - 37 that identifies certain aspects of the roadway environment that either support or detract from the safety of non-motorized users.

Traffic Safety

Rates of crashes occurring on Highway 23, and the severity of those crashes, were compared with the average rates for highways of similar type in Northeastern Minnesota. This was done in order to determine if any portions of the corridor were showing higher numbers of traffic collisions or higher rates of injury than would be expected.

Zones 5 and 6, those most urban in character, had the highest crash rates of the six zones studied in the corridor. This was anticipated because higher crash rates tend to be a function of more exposure to higher traffic volumes and greater densities of intersections and driveways. However, none of the six zones had crash rates that exceeded regional averages. Yet, Zone 6 did stand out as having a crash rate that the research literature would suggest to be higher than normal in terms of

the densities of intersections and driveways found in that segment (see Figure 3.9 on page 32). This is discussed in further detail on pages 66 and 67, which address conditions specific to that context zone.

When looking only at crashes occurring at intersections, those along the Highway 23 corridor generally have crash rates that are lower than would be expected. There are, however, three intersections that have crash rates which are higher than average for intersections of a similar type. These are the intersections of Becks Road, 75th Ave W, and 62nd Ave W (Map 3.6 on page 33). The intersection at 62nd Ave W in particular stands out as a potential concern because it has a lower-than-average crash rate but higher-than-average crash severity.

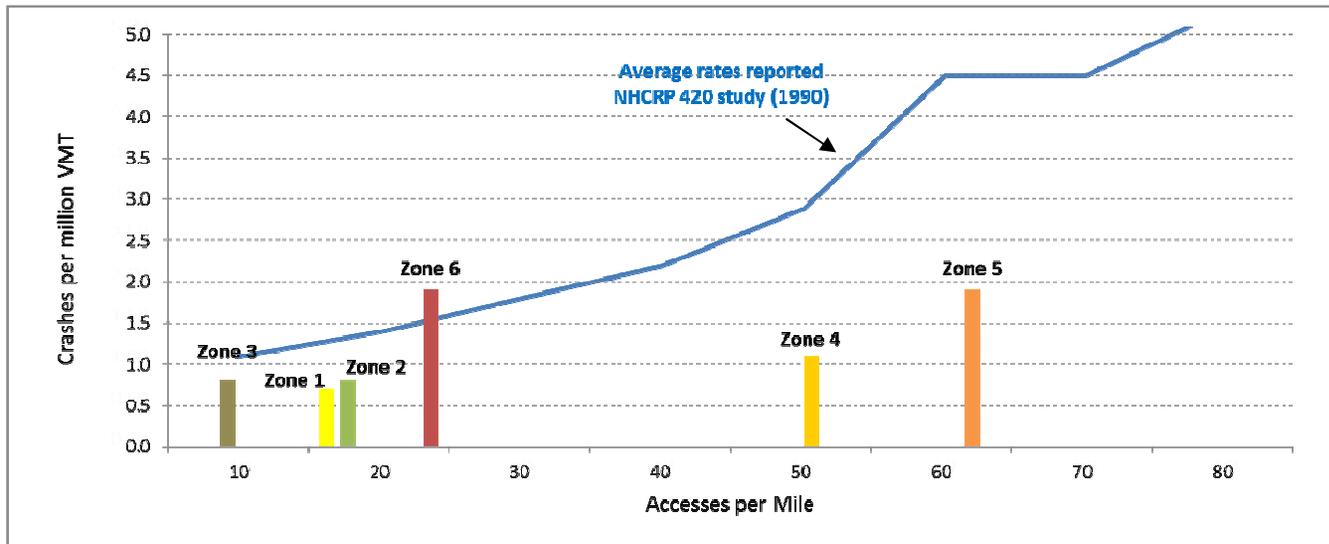
Conditions at these intersections will also be looked at more closely later in this section.

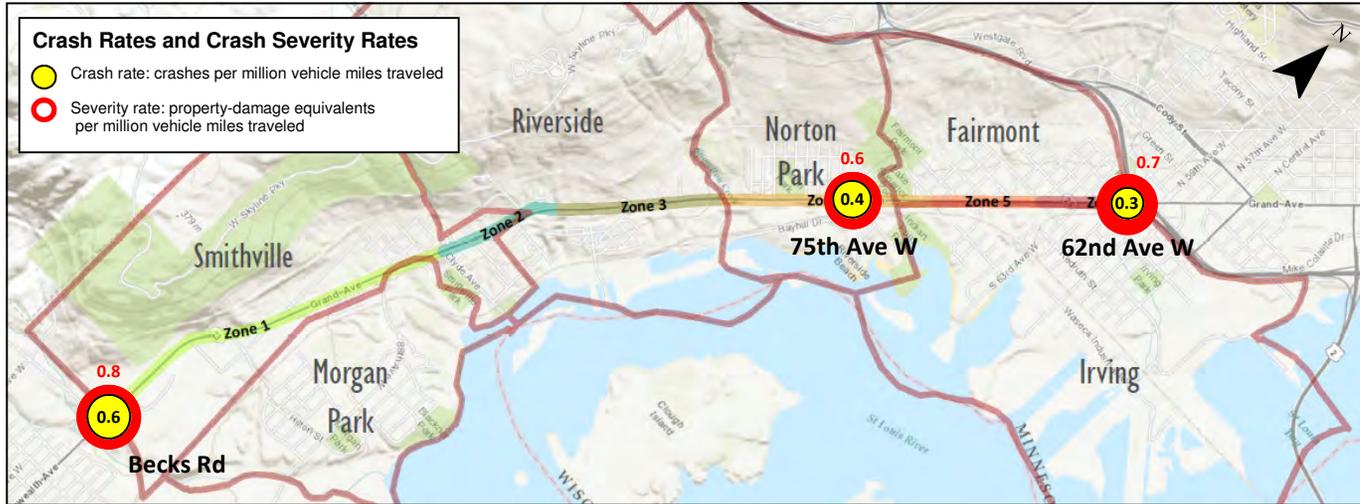
In terms of the types of crashes experienced throughout the Highway 23 corridor, rear-end crashes are the most prevalent, and failure to yield and distracted driving are common causes cited on the crash reports. These things suggest that vehicle speeds may be a predominant contributing factor in traffic incidents on this corridor.

As for the three high-crash intersections identified, crashes at Becks Road were a combination of right-angle and off-road crashes resulting only in property damage; crashes at 62nd Ave W included a high percentage of sideswipes resulting in property damage; and crashes at 75th Ave W were principally

Figure 3.9
Crash rate and access density comparisons

Although none of the context zones studied had crash rates that exceeded the area average, the rates in Zone 6 did exceed what research has indicated to be typical in terms of the densities of intersections and driveways that are found in that zone.



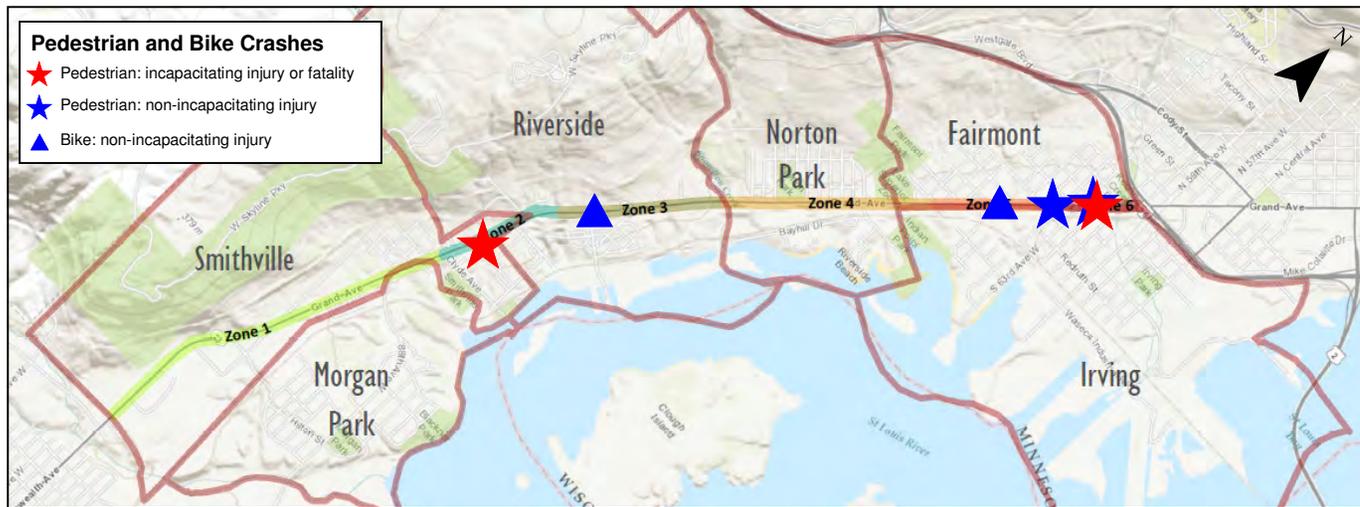


Map 3.6

Locations of intersections with above average crash rates

The map at right shows the three intersections in the study area that have had a 3-year average crash rate (yellow dot) that, since 2009, that exceeded the regional average for similar roadways. It is important to note that 62nd Ave E has a higher disparity between its crash rate and its severity rate (red circle).

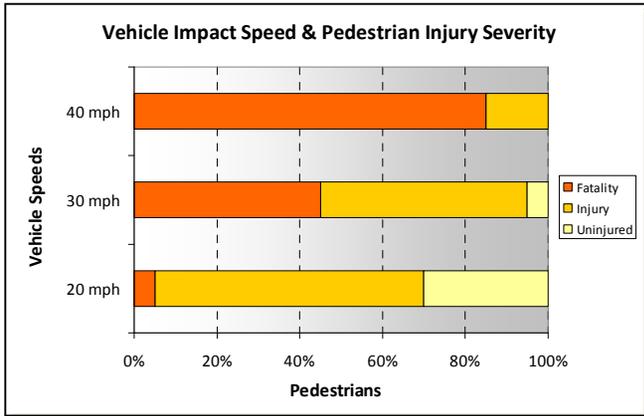
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Map 3.7

Bike & pedestrian crashes from 2003 to 2012

Four pedestrian crashes and two bike crashes occurred in the Highway 23 corridor over the past decade. The pedestrian crashes that resulted in a fatality and incapacitating injury happened in areas where vehicle speeds and potential visibility limitations are concerns.



Source: Literature review on Vehicle Travel Speeds and Pedestrian Injuries; U.S. DOT National Highway Traffic Safety Administration, 1999

Figure 3.10 | Vehicle impact speed & Severity of Injury

Research shows that pedestrians being struck by vehicles traveling at or above 40 mph face an 85% probability of being killed.

Figure 3.11 | Poor support for non-motorized users

The Highway 23 corridor is replete with conditions that do not support pedestrian or bicycle safety. The image to the left shows a location in Zone 2 where the sidewalk is crumbling and overgrown and the storm water grates present hazards for bike tires in an already narrow shoulder.



related to left-turn movements - and 50% of which were reported as resulting in possible injury or worse.

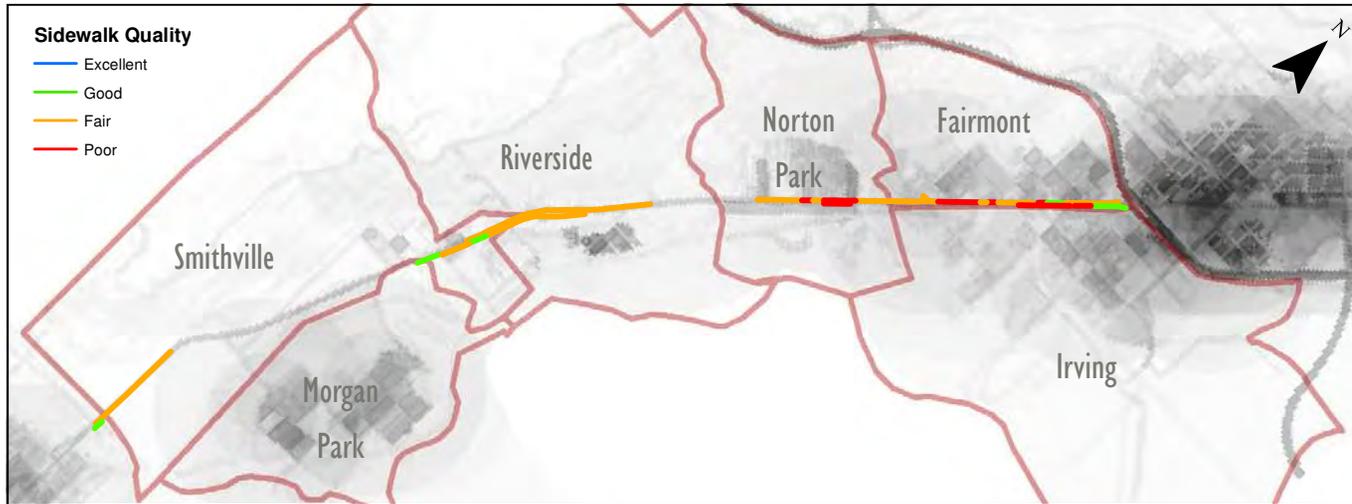
Overall, the corridor appears to be generating no more crashes than similar-type highways, and the crashes that have occurred have not resulted in large numbers of severe injuries.

Non-motorized Transportation & Safety

Six motor vehicle crashes were reported between the years 2003 through 2012 that resulted in either a cyclist or pedestrian being struck (two cyclists and four pedestrians). One of the pedestrian crashes resulted in a severe injury, and another resulted in a fatality. The locations of these crashes are shown in Map 3.7 on the preceding page, where it can be seen that most of the crashes involving either cyclists or pedestrians occurred in the more urban zones 5 and 6, where there are more driveways, more vehicles, and more limited visibility at times. The one pedestrian fatality occurred in Zone 2, more rural in character and where vehicle speeds are higher; and it also occurred at night, when there is limited lighting in the area.

Vehicle speeds are critical when it comes to the safety of non-motorized users of a highway corridor. As Figure 3.10 demonstrates, there is more than a 40% probability a pedestrian will be killed if struck by a vehicle traveling at even just 30mph. This means that Highway 23, with average free-flow speeds estimated to be above 38mph, represents a significant challenge for maintaining a safe environment for non-motorists.

As has already explained, the Highway 23 / Grand Avenue corridor is a route that is equally important for non-motorized as well as motorized movements. Treatments should therefore be sought that provide access and mobility to multiple modes in the least hazardous

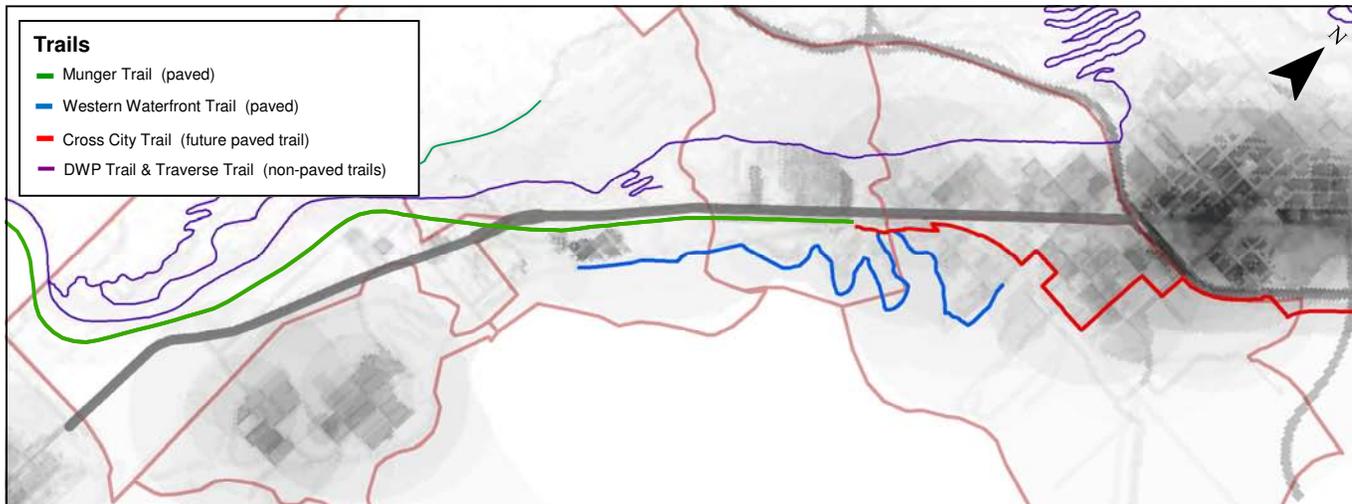


Map 3.8

Sidewalk and sidewalk condition

Approximately 1/3 of the corridor has no sidewalk on either side of the highway. A significant amount of the sidewalk in the more densely populated Fairmont and Irving neighborhoods is in poor condition.

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Map 3.9

Trail connectivity

The area of West Duluth surrounding the Highway 23 corridor contains a lot of trail amenities and potential non-motorized alternatives to the highway. But these assets lack good connectivity to the highway and the neighborhoods.



Figure 3.12 | The Munger Trail

The Munger Trail is a regional recreation trail that does not provide a lot of connections to local land uses and therefore does not serve the needs of many local bicycle commuters.



Figure 3.13 | Non-motorized crossings

There is significant non-motorized demand in the areas around Highway 23, but crossing the highway presents the biggest challenge for non-motorized travel in the corridor.

ways feasible. This includes making sure that the sidewalk network is complete and adequately maintained, that safe space is made available for cyclists, and that adequate lighting, visibility, and the necessary signage is provided. Figure 3.11 on page 34 and Map 3.8 on page 35 show how this is presently not the case in terms of the existing sidewalk network along the highway. The map, in fact, indicates that the sidewalks in the worst condition are found in the densest residential zones.

Even less support is being provided for cyclists. At present, a width of only 4 feet is available at the shoulders and even less than that in some locations. Opportunities for bike commuting off of the highway might exist, as Map 3.9 on page 35 would suggest: the existing Munger Trail and future Cross City Trail (both paved facilities), for instance, will provide for a nearly parallel route to the highway. However, connections are lacking between these assets, the neighborhoods, and other uses along the highway. Many people who identified themselves as bike commuters during the stakeholder outreach efforts for this study said that it was for this reason they do not consider the Munger/Cross City connection as a suitable alternative to Highway 23.

It should also be recognized that other trail systems exist in the area, together with a wealth of recreational opportunities around the Highway 23 corridor and the St Louis River. These amenities represent strong generators for more pedestrian and cycling activity throughout the area. This further underscores the importance for seeking ways to transition the current highway corridor into an overall safer and more supportive environment for non-motorized users.

Lastly, even if a continuous network of pedestrian- and bike-designated space was made available, non-motorists still face the challenge of crossing the highway, which is probably the biggest non-motorized travel demand throughout the corridor. It has been shown that

more than 360 transit boardings or alightings occur on any given workday, and it is conceivable that half of these movements involve someone crossing the highway. In light of this, crossing support for pedestrians should be provided throughout the corridor. This will become increasingly important as the area's general demographics continue to age and more and more people become potentially mobility challenged.

Analysis of Individual Context Zones

The following pages summarize the findings of analyses specific to the six individual context zones identified as part of this study. They call out issues and opportunities in each of the zones that may not be found in the others. Recommended treatments, therefore, are different for one segment to the next and are presented in Section 4 of this plan, beginning on page 38.

Zone 1: Becks Road to Clyde Avenue

Zone 1 is the least developed segment of the Grand Ave / Highway 23 corridor and carries the least amount of daily traffic compared to the other zones. Almost 63% of the highway in this zone is designed as a rural highway section (from Commonwealth Ave to Hulett Ave), meaning it lacks sidewalks, curb, and gutter. The roadway instead has wide, gravel shoulders like the ones seen in Figure 3.14 at right.

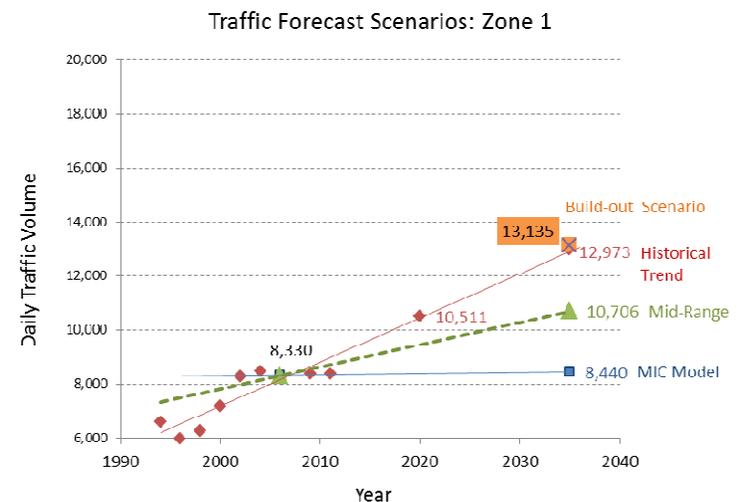
Because of the lower levels of development, the number of driveways along the highway in Zone 1 is minimal and the number turning vehicles is also low. However, this has the potential to change, as the City of Duluth is targeting the former Atlas Cement and U.S. Steele plants for up to 1.2 million ft² of future industrial



Figure 3.14 | Rural-design shoulder found in Zone 1
More than half of the length of highway 23 in Zone 1 is “rural” in design, meaning lacks sidewalk and curb and gutter.

Figure 3.15 | Future Traffic Scenarios for Zone 1

A future build out scenario of zoned industrial areas near Becks Rd suggests the potential for nearly 6,000 more vehicles per day in Zone 1. See Appendix A for explanation of forecasting methodology.



Wherever a person is getting on or off a bus, there is a potential pedestrian crossing. Based on the DTA data, it can be assumed that there is up to an average XX crossings happening throughout the corridor on a daily basis. Efforts, therefore, should be made to improve the safety of pedestrian crossings along Highway 23.



Figure 3.4 | Angled intersections in Zone 5

The section of Highway 23 / Grand Avenue between 88th Ave W and 72nd Ave W is one of the six segments identified as having a set of land use and transportation patterns unique from the rest of the highway corridor. Not only does it have higher densities of land uses, it has a plethora of angled-intersections.



LOS Criteria for Multilane Highways

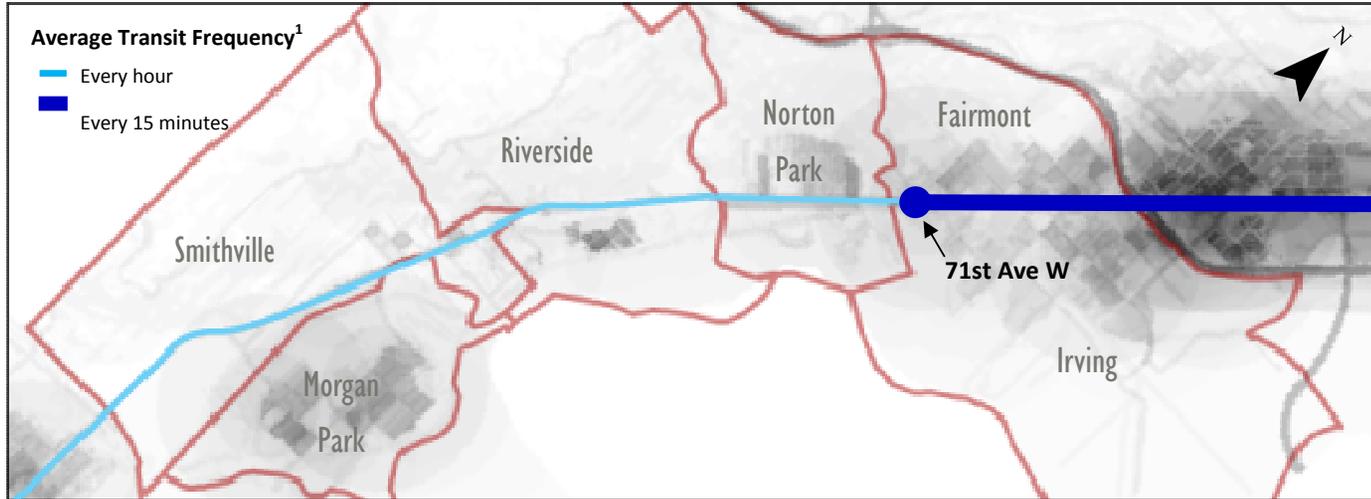
| Free-Flow Speed | Criteria | LOS | | | | |
|-----------------|--|------|------|------|------|------|
| | | A | B | C | D | E |
| 60 mi/h | Maximum density (pc/mi/ln) | 11 | 18 | 26 | 35 | 40 |
| | Average speed (mi/h) | 60.0 | 60.0 | 59.4 | 56.7 | 55.0 |
| | Maximum volume to capacity ratio (v/c) | 0.30 | 0.49 | 0.70 | 0.90 | 1.00 |
| | Maximum service flow rate (pc/h/ln) | 660 | 1080 | 1550 | 1980 | 2200 |
| 55 mi/h | Maximum density (pc/mi/ln) | 11 | 18 | 26 | 35 | 41 |
| | Average speed (mi/h) | 55.0 | 55.0 | 54.9 | 52.9 | 51.2 |
| | Maximum v/c | 0.29 | 0.47 | 0.68 | 0.88 | 1.00 |
| | Maximum service flow rate (pc/h/ln) | 600 | 990 | 1430 | 1850 | 2100 |
| 50 mi/h | Maximum density (pc/mi/ln) | 11 | 18 | 26 | 35 | 43 |
| | Average speed (mi/h) | 50.0 | 50.0 | 50.0 | 48.9 | 47.5 |
| | Maximum v/c | 0.28 | 0.45 | 0.65 | 0.86 | 1.00 |
| | Maximum service flow rate (pc/h/ln) | 550 | 900 | 1300 | 1710 | 2000 |
| 45 mi/h | Maximum density (pc/mi/ln) | 11 | 18 | 26 | 35 | 45 |
| | Average speed (mi/h) | 45.0 | 45.0 | 45.0 | 44.4 | 42.2 |
| | Maximum v/c | 0.26 | 0.43 | 0.62 | 0.82 | 1.00 |
| | Maximum service flow rate (pc/h/ln) | 490 | 810 | 1170 | 1550 | 1900 |

Note:

The exact mathematical relationship between density and volume to capacity ratio (v/c) has not always been maintained at LOS boundaries because of the use of rounded values. Density is the primary determinant of LOS. LOS F is characterized by highly unstable and variable traffic flow. Prediction of accurate flow rate, density, and speed at LOS F is difficult.

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From Highway Capacity Manual, 2000



1. Average frequency for service provided between 4:30 AM and 12:00 AM.