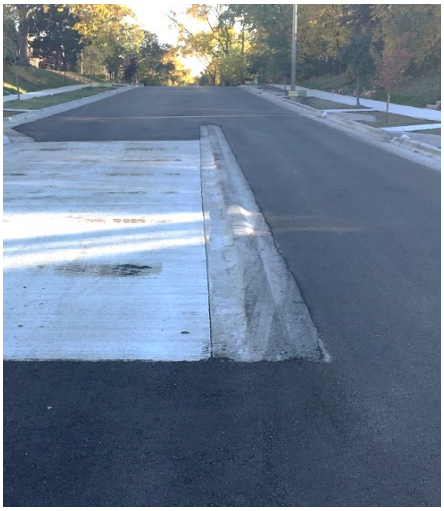
Minneapolis
Public Works

Evaluation of Vertical Lane Separation Treatments at In-Lane Bus Stops



October 2024

Last updated 10/22/24

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Executive Summary

Overview

Public Works first installed vertical lane separation treatments at in-lane bus stops in 2021. The intent of these treatments is to discourage drivers from going into the oncoming traffic lane if passing buses stopped at in-lane bus stops. This evaluation focuses specifically on raised hardened centerlines and medians at select in-lane bus stops within Minneapolis to both understand their effectiveness at reducing vehicle passing and identify maintenance challenges. This evaluation will be used to inform the use of these treatment types in future roadway projects within the city.

This evaluation includes nine study locations, each noted below:

- Control – no treatment
  - Penn Ave N and 36th Ave N
  - Penn Ave N and Dowling Ave N
- Raised hardened centerline
  - Fremont Ave N and 35th Ave N
  - Fremont Ave N and Dowling Ave N
  - Fremont Ave N and 42nd Ave N
  - Grand Ave S and W 34th St
- Median
  - Johnson St NE and 22nd St NE
  - Penn Ave N and Plymouth Ave N
  - Grand Ave S and W 43rd St


Control


Raised Hardened Centerline


Median

Staff collected both qualitative and quantitative data as part of this evaluation. Metrics that were studied and recorded include:

- Vehicle passing rates at in-lane bus stops: to understand if and how the various vertical lane separation treatment types affect driver behaviors
- Pedestrian crossing behaviors: to understand where and how pedestrians are crossing at intersections with raised hardened centerlines in comparison to locations with no treatment
- Before and after crash data: to understand the impact of the vertical lane separation treatments on user safety – measured through both crash frequency and crash rates
- 311 data and emails to City staff from community members: to understand user feedback
- City staff feedback: to understand winter maintenance needs and design/installation lessons learned

Key Findings

After reviewing and analyzing the qualitative and quantitative data collected for this study, staff identified the following key findings:

- There is variability in the design of raised hardened centerlines across the study locations such as the length of the treatment and where it begins and ends relative to the intersection; all locations meet current SDG guidance.
- The inclusion of vertical lane separation treatments at in-lane bus stops showed a correlation to reducing the percentage of vehicles that passed stopped buses at transit stops.
- Locations with medians saw the lowest percentage of vehicles passing buses at transit stations (3%).
- Nearside station locations had a lower percentage of vehicles passing stopped buses (8%) than farside station locations (24%).
- Signalized station locations had a lower percentage of vehicles passing stopped buses (12%) than non-signalized/stopped controlled locations (21%).
- There was a higher compliance of pedestrians crossing in the crosswalk, rather than over the centerline, at locations with raised hardened centerlines (80%) than at control (no treatment) locations (51%).
- All study locations with vertical lane separation treatments saw a decrease or no change in crash frequency and crash rates after the installation of the raised hardened centerline or median.
- A total of six 311 comments and four emails to staff were received between 2018 and 2023 (all during winter months) that directly relate to raised hardened centerlines; the majority noted that raised hardened centerlines can be difficult to see for both people walking and driving, especially in winter.
- Snowplow blades consistently run on top of the raised hardened centerline which causes a strip of snow left behind on either side which can lead to visibility issues.
- Snowplow blades have scraped away the top of the concrete of some raised hardened centerlines causing damage to the concrete.

Staff Recommendations

Given the findings of this evaluation, staff recommend the following:

1. Continue the use of vertical lane separation treatments at in-lane bus stops; specifically medians.
    - Medians are the preferred design treatment at in-lane bus stops since they had lower vehicle passing rates, lower crash rates, no usability concerns raised from the public, and fewer maintenance concerns.
    - Raised hardened centerlines should no longer be used due to user safety concerns for people walking and driving.
        - Existing raised hardened centerlines along Fremont Ave N and Grand Ave S have been modified to include yellow paint along the top of the curb to help improve visibility. These locations should continue to be monitored.
2. In coordination with the Street Design Guide core team, update Street Design Guide language for medians and raised hardened centerlines at in-lane bus stops.
    - Remove language regarding raised hardened centerlines.
    - Provide additional design details for allowable median widths in constrained corridors.

Overview

Public Works first installed vertical lane separation treatments at in-lane bus stops in 2021 with the METRO D Line. The intent of these treatments is to discourage drivers from going into the oncoming traffic lane to pass buses stopped at in-lane bus stops. There are three primary types of vertical lane separation treatments that Public Works deploys. Figure 1, below, shows the three different treatment types. These include:

- Raised hardened centerlines – a short, narrow curb that runs along the centerline
- Medians – standard height curb, generally 4' wide or greater
- Bollard hardened centerlines – quick-build bollards located along the centerline

This evaluation focuses specifically on raised hardened centerlines and medians at select in-lane bus stops within Minneapolis. This evaluation does not focus on bollard hardened centerlines for two reasons: first, bollard hardened centerlines are primarily focused on slowing left turning vehicles at intersections, not reducing vehicle passing at in-lane bus stops; second, bollard hardened centerlines have been proven to be an effective traffic calming treatment as shown in evaluations that other jurisdictions have completed[1][2][3].

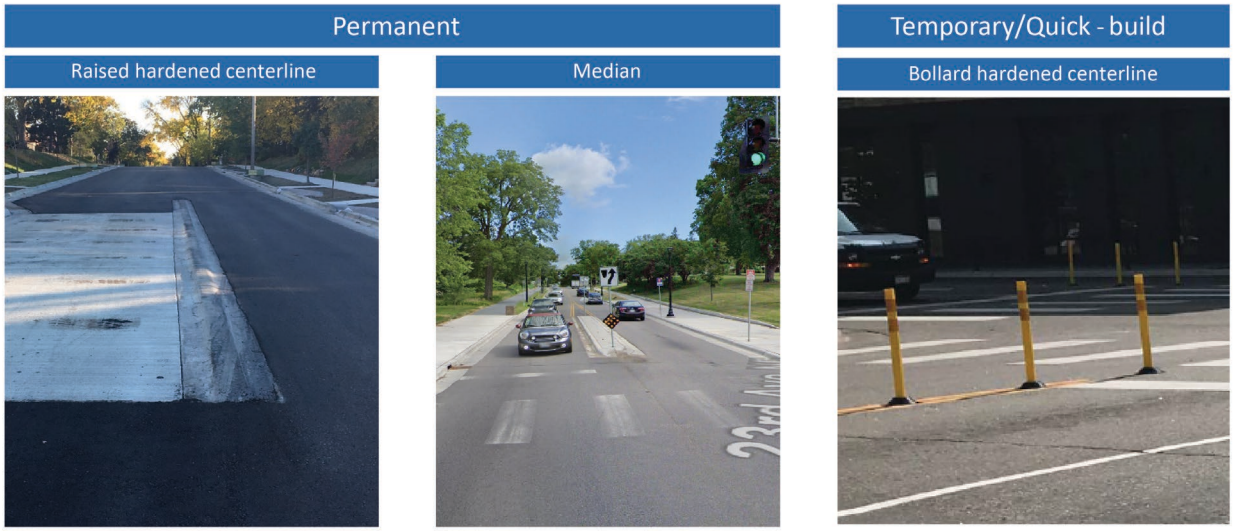


Figure 1: Vertical lane separation treatment types

The City of Minneapolis Street Design Guide (SDG) provides guidance on using vertical lane separation treatments, such as raised hardened centerlines and medians, at in-lane but stops. Details can be found here and in Appendix A.

The deployment of vertical lane separation treatments at in-lane bus stops, especially raised hardened centerlines, is a relatively new (2021+) treatment being used in Minneapolis. The purpose of this evaluation is to assess raised hardened centerlines and medians at in-lane bus stops to understand their effectiveness at reducing vehicle passing, visibility for people walking and driving, and identifying any additional maintenance

[1] https://www.iihs.org/topics/bibliography/ref/2202
[2] https://www.nyc.gov/html/dot/html/pedestrians/turn-calming.shtml#results
[3] https://www.portland.gov/sites/default/files/2020-07/left-turn-calming-evaluation-report.pdf

needs. Metro Transit recently completed a similar evaluation study, focusing specifically on raised hardened centerlines along the METRO D Line along Fremont Ave N. The City and Metro Transit shared data during the development of this evaluation report and Metro Transit's report.

Methodology

Goals of Evaluation

The goal of this evaluation is to understand how vertical lane separation treatment types – raised hardened centerlines and medians – function in real life conditions to inform decisions related to inclusion in future projects and/or any design modifications needed. This evaluation focuses on operational observations, winter maintenance, seasonal functionality (ice/rain), and user experience. Staff used the following research questions as the basis of this evaluation work:

- Do vertical lane separation treatments prevent vehicles from passing stopped buses at in-lane bus stops?
- How do the different vertical lane separation treatments function in various weather conditions, including winter? Are there specific maintenance challenges?
- When and how should vertical lane separation treatments be used in future projects?

This evaluation will inform the use of these treatment types in future roadway projects within the city by incorporating key findings into relevant updates in the SDG.

Evaluation Metrics and Methods

Staff collected both qualitative and quantitative data as part of this evaluation. Metrics that were studied and recorded include:

- Vehicle passing rates at in-lane bus stops: to understand if and how the various vertical lane separation treatment types affect driver behaviors
- Pedestrian crossing behaviors: to understand where and how pedestrians are crossing at intersections with raised hardened centerlines and control locations
- Before and after crash data: to understand the impact of the vertical lane separation treatments on user safety – measured through both crash frequency and crash rates
- 311 data: to understand user feedback
- City staff feedback: to understand winter maintenance needs and design/installation lessons learned

Data collection methods for each metric can be found in Table 1, below.

Table 1: Data collection method for each metric

Metric	Time Period	Method
Vehicle passing rates at in-lane bus stops	October 3rd and 4th, 2023	13-hour video footage (6am-7pm) collected for each study location and reviewed/recorded by City staff
Pedestrian crossing behaviors	October 3rd and 4th, 2023	13-hour video footage (6am-7pm) collected for each study location and reviewed/recorded by City staff

Before and after crash frequency and crash rates	Before – varies by study location; 3-years pre-installation of treatment type After – varies by study location; 2- or 3-years post-installation of treatment type, depending on available data	Crash data obtained from Minnesota Crash Mapping Analysis Tool (MnCMAT2) AADT obtained from MnDOT's Traffic Mapping Application and Miovision
311 Data	2018-2023	Data obtained from City of Minneapolis 311 Department

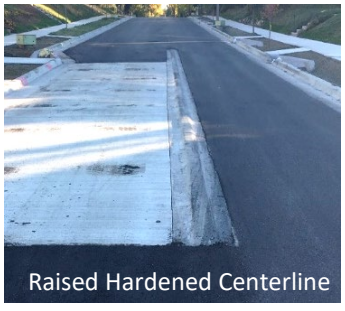
Study Locations

This study includes nine study intersections across Minneapolis – two control intersections that do not have any vertical lane separation treatment, four intersections that have raised hardened centerlines, and three locations that have medians. All study intersections selected for this evaluation have in-lane bus stops and they include a mix of Bus Rapid Transit (BRT)[4] and local bus service, a mix of both nearside[5] and farside[6] station locations, and a mix of signalized and non-signalized intersections.

The locations included in this study are noted below and shown in Figure 2.

- Control – no treatment
  - Penn Ave N and 36th Ave N
  - Penn Ave N and Dowling Ave N
- Raised hardened centerline
  - Fremont Ave N and 35th Ave N
  - Fremont Ave N and Dowling Ave N
  - Fremont Ave N and 42nd Ave N
  - Grand Ave S and W 34th St
- Median
  - Johnson St NE and 22nd St NE
  - Penn Ave N and Plymouth Ave N
  - Grand Ave S and W 43rd St


Control


Raised Hardened Centerline


Median

[4] Bus Rapid Transit (BRT) is a high frequency bus route that provides service that is up to 25% faster than local bus service due to signal priority, wider stop spacing, off-board payments, and all-door boarding. Additionally, BRT typically includes more amenities at the station locations than typical transit stops.
[5] Nearside station locations are located just before the intersection.
[6] Farside station locations are located just after the intersection.

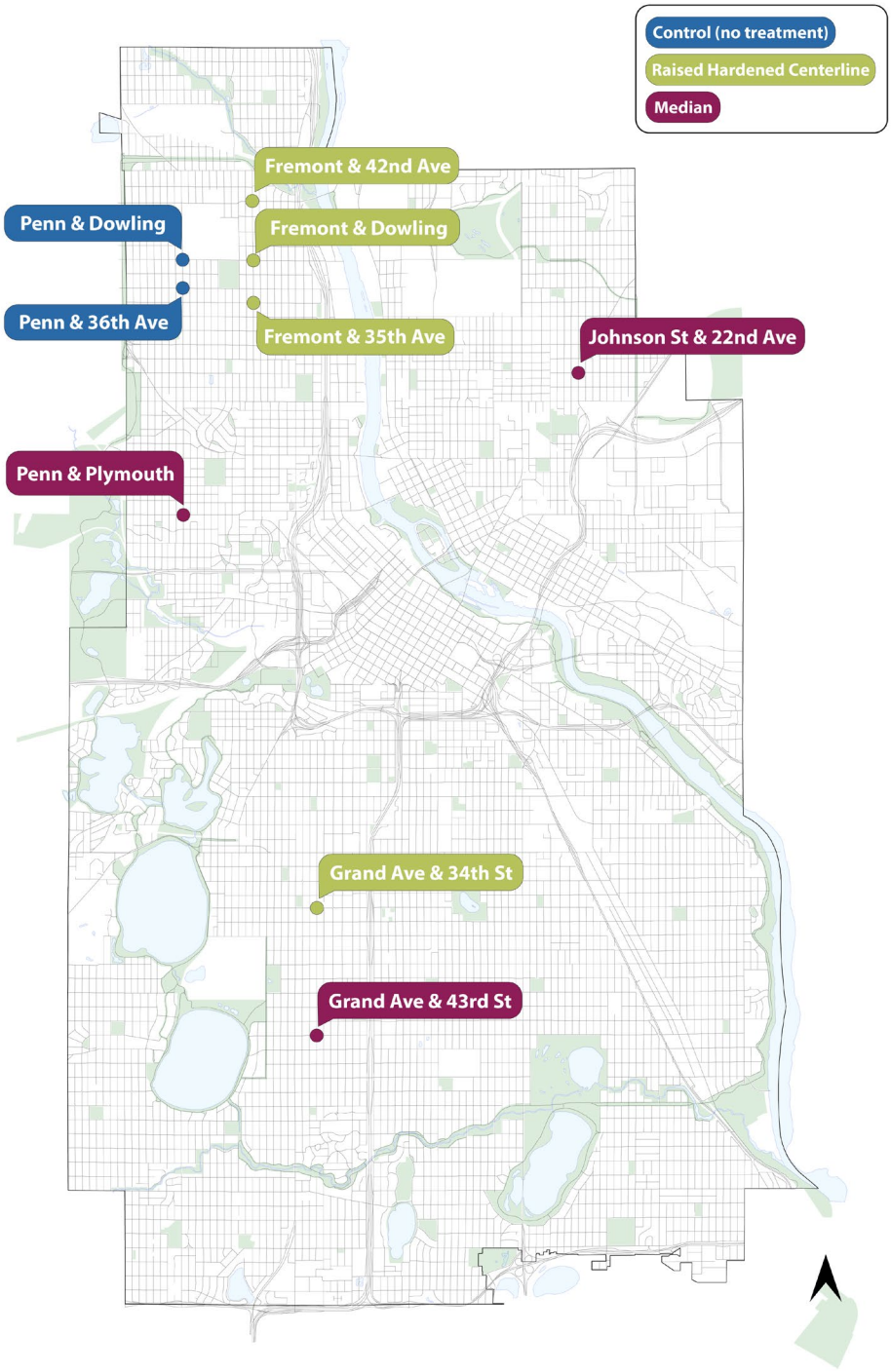


Figure 2: Map of study locations

Study Location Characteristics

Table 2, below, outlines the intersection characteristics for each of the locations included in this study. The table includes the treatment type, location, treatment install year, type of traffic control, transit route type, transit station location, roadway speed limit, and additional location and design context that is relevant to this study.

Although there is variability in the design of the raised hardened centerlines in regard to placement at intersection and centerline length (noted in the "Additional Notes" column in Table 2 below), all study locations with raised hardened centerlines align with current SDG guidance for this treatment type.

Table 2: Study locations and characteristics

Treatment Type	Location	Treatment Install Year	Traffic Control	Transit Route Type	Transit Station Location	Speed Limit	Additional Notes
Control (no treatment)	Penn Ave N & 36th Ave N	C Line improvements installed 2019	Two-way stop control on 36th Ave N	BRT (C Line)	Farside	30 MPH	-
	Penn Ave N & Dowling Ave N	C Line improvements installed 2019	Signal	BRT (C Line)	Nearside	30 MPH	All four approaches have bollard hardened centerlines between crosswalk and stop bar installed in 2021
Raised hardened centerline	Fremont Ave N & 35th Ave N	2021	Two-way stop control on 35th Ave N	BRT (D Line)	Farside	25 MPH	Raised hardened centerlines are 90' and 100' on the northbound and southbound approaches, respectively. It continues through the crosswalk on both north and south legs
	Fremont Ave N & Dowling Ave N	2021	Signal	BRT (D Line)	Farside	25 MPH	Raised hardened centerlines are 75' and 90' on the northbound and southbound approaches, respectively. It ends directly behind the crosswalk on both north and south legs
	Fremont Ave N & 42nd Ave N	2021	Signal	BRT (D Line)	Nearside	25 MPH	Raised hardened centerlines are 100' on both the northbound and southbound approaches. The raised hardened centerline on the north leg stops at the stop bar (approx. 10' back from crosswalk), south leg stops behind the stop bar (approx. 15' from crosswalk). All four approaches have bollard hardened centerlines installed in 2022
	Grand Ave S & 34th St W	2021	Signal	Limited Stop (113)	Nearside	25 MPH	Raised hardened centerlines are 75' on both the northbound and southbound approaches. Both end directly behind the crosswalk on the north and south legs

Median	Grand Ave S & 43rd St W	2021	Two-way stop control on 43rd St W	Limited Stop (113)	Nearside	25 MPH	Median continues through the crosswalk on both north and south legs
	Penn Ave N & Plymouth Ave N	2021	Signal	BRT (C Line)	Farside	30 MPH	Median on north leg begins approx. 40' back from the crosswalk; median on the south leg begins approx. 35' back from the crosswalk
	Johnson St NE & 22nd Ave NE	2021	RRFB	Hi-Frequency (Route 4)	Nearside	25 MPH	Median continues through the crosswalk on both north and south legs

Key Findings

Vehicle Passing Rates at In-Lane Bus Stops

City staff collected 13-hour video at each of the study locations and recorded observations. Table 3, below, summarizes the percent of vehicles that went into the oncoming travel lane to pass stopped buses at the study locations.

The inclusion of vertical lane separation treatments at in-lane bus stops showed a correlation to reducing the percentage of vehicles that passed stopped buses at transit stops. At control intersections where no treatment is included, vehicles passed stopped buses 34% of the time during the observation period, whereas locations with raised hardened centerlines and medians saw a lower percentage of vehicles passing – 11% and 3% respectively. Additionally, it was observed that nearside station locations have an overall lower vehicle passing rate than farside stations and signalized intersections have an overall lower vehicle passing rate than two-way stop-controlled intersections; this was seen at both control and treatment intersections. Full data collection of vehicle passing rates can be found in Appendix B.

Table 3: Vehicle passing rates

Treatment Type	# instances when bus was stopped with vehicle behind (opportunity for passing)	% Vehicles Passing Stopped Buses				
		Nearside Stations	Farside Stations	Signalized Intersections	Two-way Stop Controlled Intersections	**All Study Intersections**
Control (no treatment)	211	23%	45%	23%	45%	**34%**
Raised hardened centerline	281	2%	20%	8%	19%	**11%**
Median	126	0%	8%	4%	0%	**3%**

Pedestrian Crossing Behaviors

Pedestrian crossing behaviors were observed at each of the study locations with raised hardened centerlines and the control intersections. The purpose of this observation is to understand whether people crossing the street are doing so in the crosswalk or walking over the centerline. This is important to understand as there have been a few reported incidents, both through 311 data (noted in Table 6 below) and in emails directly to staff, noting that people have tripped over the raised hardened centerline. This observation did not include median study intersections since no concerns of visibility or tripping have been raised at these locations.

Table 4, below, summarizes the total number of pedestrians who crossed the street at control locations and study locations with raised hardened centerlines. Pedestrians were only counted if they were crossing at the leg of the intersection where the in-lane bus stop or raised hardened centerline is located.

There was a higher compliance of pedestrians crossing in the crosswalk at study locations (80%) than at control locations (51%). A higher percentage of people were observed crossing in the crosswalk at nearside bus stops for both control (65%) and study locations (90%) than at farside bus stop locations for control (36%) and study locations (70%).

Of the intersections with raised hardened centerlines, the intersection of Fremont Ave N and Dowling Ave N saw the highest percentage of pedestrians crossing over the hardened centerline with it occurring 33% of the time. From staff observations of the video footage collected, there was significant pedestrian movement between the northside bus stop location and the convenience store located on opposite side of Fremont Ave N. It was observed that people often took the shortest path between the two destinations, crossing north of the intersection over the raised hardened centerline.

Staff has received two emails (February 2023 and January 2024) noting two separate instances of someone tripping over a raised hardened centerline. No instances of people tripping over the raised hardened centerlines were observed during the video observations. Full data collection of pedestrian crossing behaviors can be found in Appendix C.

Table 4: Pedestrian crossing behaviors

Study Locations	Treatment Type	Bus Stop Station location	Total # Pedestrians Crossing	% of Pedestrians Crossing in the Crosswalk	% of Pedestrians Crossing Over the Centerline or Raised Hardened Centerline
Penn Ave N & 36th Ave N*	Control – no treatment	Farside	399	36%	64%
Penn Ave N & Dowling Ave N*	Control – no treatment	Nearside	168	65%	35%
Fremont Ave N & 35th Ave N*	Raised hardened centerline	Farside	149	72%	28%

Fremont Ave N & Dowling Ave N	Raised hardened centerline	Farside	183	67%	33%
Fremont Ave N & 42nd Ave N*	Raised hardened centerline	Nearside	268	88%	12%
Grand Ave S & W 34th St	Raised hardened centerline	Nearside	196	91%	9%

* Select intersections only included 12-hour video observations (7am to 7pm). Video footage was not visible enough between 6am-7am to make accurate observations due to lack of lighting at the intersections.

Crash Data

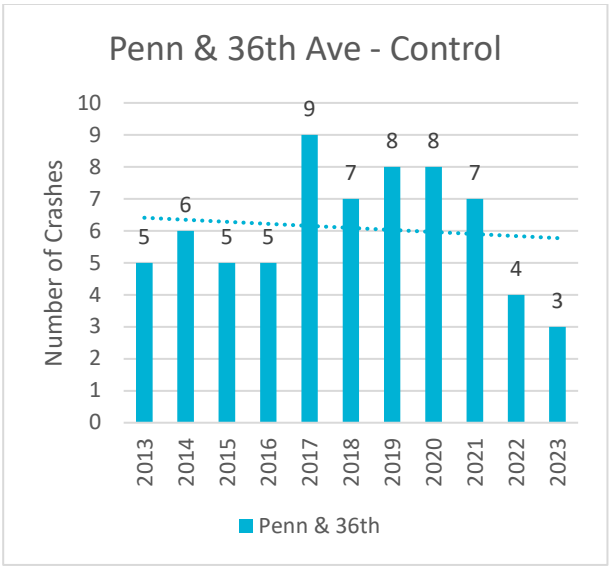
Crash frequency and crash rates were examined for all study locations as part of this evaluation. All study locations with vertical lane separation treatments saw a decrease in crash frequency and crash rates after the installation of the raised hardened centerline or median. Study locations with vertical lane separation treatments had lower crash rates overall than the control intersections.

Crash Frequency

Crash frequency[7] was measured before and after installation for each study location. All study locations saw a decrease in the total number of crashes before and after installation. Figure 3, below, shows graphs of the crash frequencies of the control intersections. Figure 4 shows the crash frequencies for study locations with raised hardened centerlines, and Figure 5 shows the crash frequencies for study locations with medians. Figures 3, 4 and 5 all include crash data from 2013 through 2023. It is important to note that other safety improvements, such as narrowing the roadway and bump outs, were made at all study locations in addition to the inclusion of raised hardened centerlines and medians. It is likely that these improvements have an impact on the crash frequencies as well.

Crash summaries for each of the study locations can be found in Appendix D.

[7] Crash frequency measures the number of crashes occurring at a specific location over a period of time.



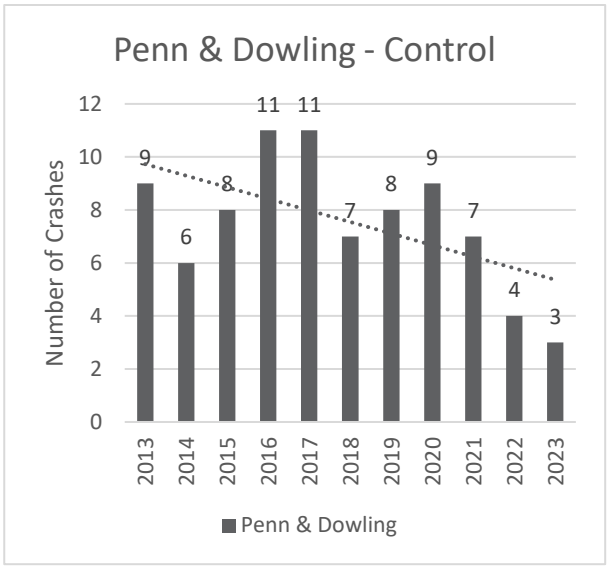
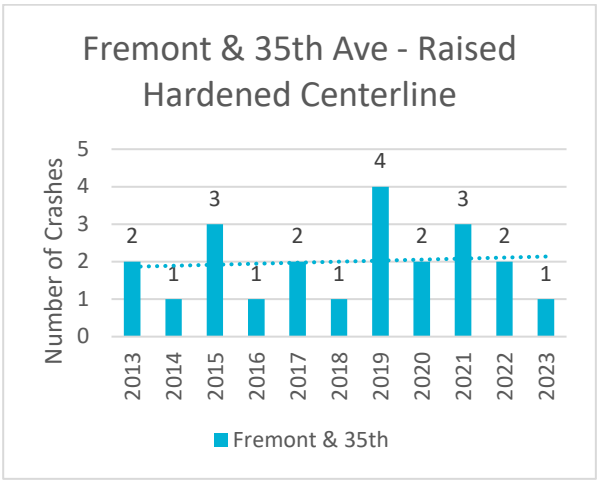
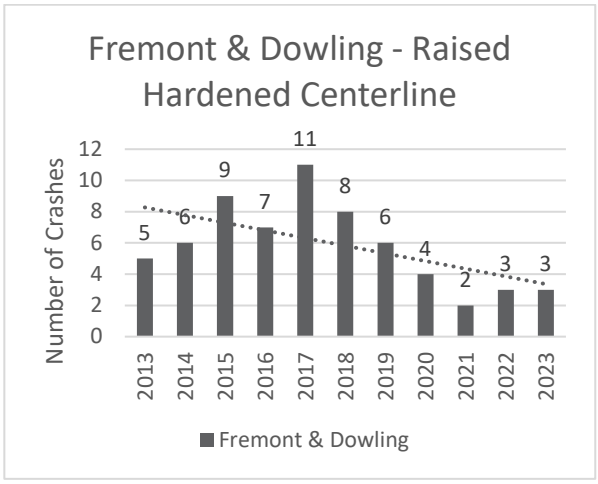
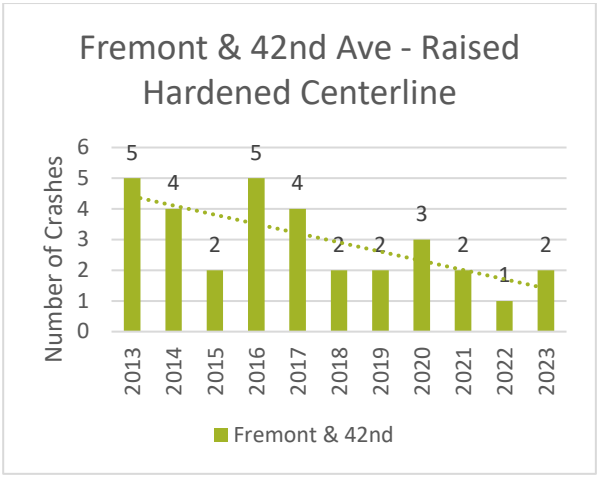


Figure 3: Crash frequencies at control intersections

As shown in Figure 3 above, crash frequencies at the control intersections peaked in 2017 – the year before construction for C Line began (2018). Crashes decreased in 2020, the first full year of C Line operations, compared to 2017. Since 2020, crashes have been consistently decreasing at the control locations through 2023.







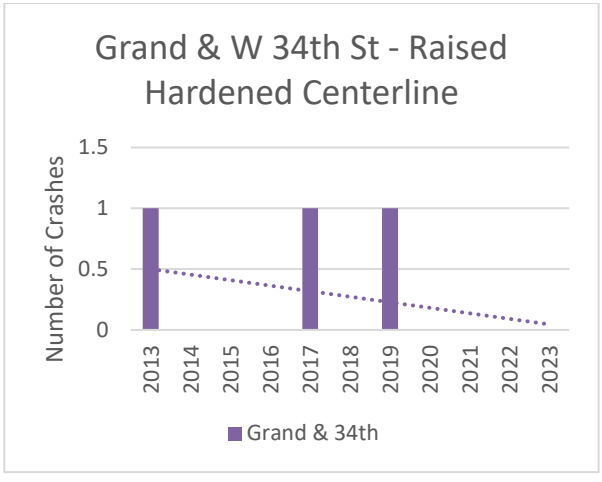
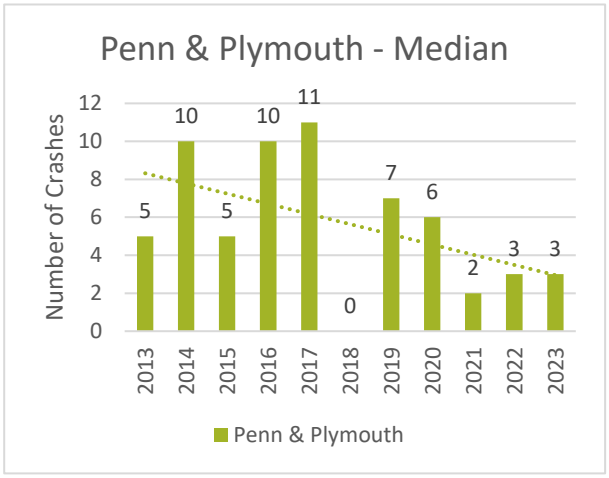
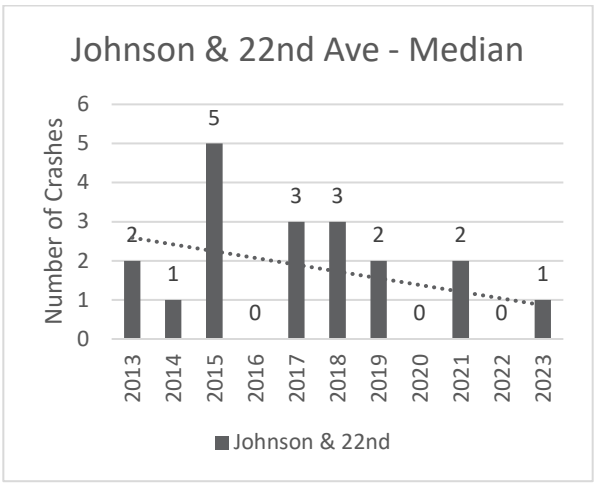


Figure 4: Crash frequencies at study locations with raised hardened centerlines

Raised hardened centerlines were installed along Fremont Ave N in fall 2021 and along Grand Ave S in fall 2022. As shown in Figure 4 above, Fremont & 35th Ave has seen a decrease in crashes since the installation of the raised hardened centerline. Fremont & Dowling and Fremont & 42nd Ave both saw little to no change in the number of crashes after the installation of the raised hardened centerline. Grand & W 34th St did not have any crashes the 2 years leading up to the installation of the raised hardened centerline and has not had any reported crashes since the installation.





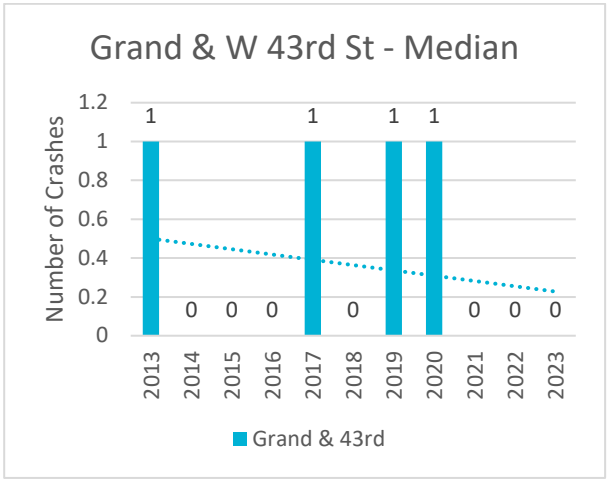


Figure 5: Crash frequencies at study locations with medians

Medians were installed at Penn & Plymouth and Johnson & 22nd Ave in 2021 and at Grand & W 43rd St in 2022. The medians at both Johnson & 22nd Ave and Grand & W 43rd St were both installed as part of larger corridor reconstruction projects. As shown in Figure 5 above, crash frequencies at study locations with medians all saw a decrease in crashes in the years after the installation of medians.

The study location of Penn Ave N and Plymouth Ave N is particularly interesting, because C Line improvements were installed in 2018-2019 at this location but the median was not installed until 2021. There was a slight decrease in crashes after improvements were made in 2019 with the C Line. Crashes reduced by approximately 50% when comparing post-C Line improvements and after the installation of the median.

Crash Rates

Intersection crash rates[8] were measured before and after for each study location. Intersection crash rates were determined using the following calculation:

$$R = \frac{1{,}000{,}000 \text{ x } C}{365 \text{ x } N \text{ x } V}$$

Where:

- R = crash rate for the intersection expressed as crashes per million entering vehicles
- C = total number of intersection crashes in the study period
- N = number of years of data
- V = traffic volumes entering the intersection daily

Crash rates were calculated using 2- or 3-year pre and post installation data, depending on available data. Table 5, below, outlines the before and after data used for each study location as well as the calculated before and after crash rates.

Every study location saw a decrease in crash rates after installation, except for Penn Ave N and 36th Ave N, which saw no change. Control intersections had a 16% average decrease in after crash rates, raised hardened centerline locations had a 50% average decrease in after crash rates, and locations with medians had a 60% average decrease in after crash rates. After crash rates for locations with raised hardened centerline and medians were all lower than those of the control intersections.

Table 5: Crash Rates

Treatment Type	Study Location	Intersection Type	Before Data (years)	After Data (years)	Before Crash Rate	After Crash Rate	% Change in Crash Rate	Average % Change in Crash Rate by Treatment Type
Control (no treatment)	Penn Ave N & 36th Ave N	C Line construction impacts began March 2018 and was completed June 2019	2015-2017	2020-2022	1.89	1.89	-0%	-16%
	Penn Ave N & Dowling Ave N	C Line construction impacts began March 2018 and was completed June 2019	2015-2017	2020-2022	1.84	1.23	-33%	

[8] A crash rates analysis is used to determine the relative safety of a segment or intersection.

Raised hardened centerline	Fremont Ave N & 35th Ave N	D Line construction impacts began Spring 2021 and were completed December 2021	2019-2020	2022-2023	2.45	1.22	-50%	-50%
	Fremont Ave N & Dowling Ave N	D Line construction impacts began Spring 2021 and were completed December 2021	2019-2020	2022-2023	1.05	0.63	-40%	
	Fremont Ave N & 42nd Ave N	D Line construction impacts began Spring 2021 and were completed December 2021	2019-2020	2022-2023	0.98	0.59	-40%	
	Grand Ave S & 34th St W	This segment of Grand Ave S reconstruction was completed in 2022	2019-2020	2022-2023	0.45	0.00	-100%	
Median	Grand Ave S & 43rd St W	This segment of Grand Ave S reconstruction was completed in 2021	2019-2020	2022-2023	0.89	0.00	-100%	-60%
	Penn Ave N & Plymouth Ave N	C Line construction began March 2018 and was completed June 2019; the medians were installed in late 2021	2020-2021	2022-2023	0.93	0.70	-25%	
	Johnson St NE & 22nd Ave NE	Johnson St NE reconstruction began May 2021 and was completed late 2021	2019-2020	2022-2023	0.22	0.11	-50%	

Full data used to calculate crash rates for each study location can be found in Appendix E.

311 Data & Public Feedback

To understand public feedback on vertical lane separation treatment types, community member emails to City staff were reviewed and 311 data was pulled for all study locations and reviewed to extract feedback specific to raised hardened centerlines and medians at in-lane bus stops. For this portion of the evaluation, data was also pulled for all raised hardened centerline locations across the city to ensure staff captured as much public feedback as available. The following intersections were included in the 311 data review in addition to the study locations included in this evaluation:

- Grand Ave S and W 31st St
- Grand Ave S and W 33rd St
- Grand Ave S and W 35th St
- Grand Ave S and W 37th St
- Grand Ave S and W 38th St
- Grand Ave S and W 39th St
- Grand Ave S and W 40th St
- Grand Ave S and W 42nd St
- Grand Ave S and W 44th St
- Grand Ave S and W 46th St
- Grand Ave S and W 48th St

There was a total of four community member emails sent to City staff and six 311 comments filed between 2018 and 2023 that directly relate to vertical lane separation treatments at in-lane bus stops. All of the 311 comments filed are noted below in Table 6.

All comments received via email and 311 were in regard to raised hardened centerlines and were filed during winter months. The majority of the comments note that the raised hardened centerline can be difficult to see both for people walking and people driving, especially with snow. Community members noted that the lack of visibility has created safety issues for people walking and driving.

Table 6: 311 data regarding vertical lane separation treatments

Date Created	Intersection	Complaint/Comment Description
1/26/2022	Fremont Ave N & 42nd Ae N; Fremont Ave N & 35th Ave N	There are 2 sets of lane medians on Fremont Ave N between 33rd & 42nd that are fairly new. They are difficult to see in the snow. Can they be painted yellow so they are more visible?
3/10/2022	Grand Ave S & W 48th St	Caller states there are concrete dividers here that are not marked and people are hitting them with their cars
3/14/2022	Grand Ave S & W 48th St	Caller states there are concrete dividers where that are not marked and people are hitting them with their cars – caller would like the concrete dividers removed from this location
1/9/2023	Grand Ave S & W 34th St	On Grand Ave S just before 34th St in the middle of the street – please re-plow and sand due to car accident caused when resident hit the invisible, narrow curb that was buried in the snow. Injury/Damage notes: caller spun out of control upon hitting the unmarked curb to avoid oncoming vehicle

2/3/2023	Grand Ave S & W 48th St	Grand Ave S – the issue are the small curb size medians in the middle of Grand Ave S. Keep in mind there are three schools in the area. There are often students and parents walking to and from school.
2/13/2023	Grand Ave S & W 38th St	Hardened centerline crossing Grand Ave S – caller tripped over the hardened centerline and broke her arm. She didn't see it as it blends in with bus pad. Can these new hardened centerlines on Grand Ave S be painted yellow to precent pedestrians from getting hurt?

City Staff Feedback

This evaluation study was conducted with a Public Works core team that involved staff from the following divisions:

- Transportation Planning and Programming
- Traffic and Parking Services
- Transportation Engineering and Design
- Transportation Maintenance and Repair
- Surface Waters and Sewers

This group was used to solicit subject matter expert feedback on vertical lane separation treatments to understand any maintenance or operational challenges as well as guide the evaluation work. Key feedback received from City staff noted the following:

- The concrete of the raised hardened centerlines is being damaged by plow blades, shown in Figure 6 below; it is essentially being shaved off by plow blades, most notably at the start and end of the raised hardened centerlines.
- Snowplow blades ride up over the raised hardened centerline, leaving a small strip of snow that can't be cleared, shown in Figure 7 below; this can lead to visibility challenges of the raised hardened centerline in wintertime, also noted in the comments received through 311 and emails to City staff.
- The narrowness between the vertical lane separation treatment and curb can pose challenges with both snow clearing and vehicles operating in the space.
    - Current City snowplows need 11' clearance between curbs for snow clearing – all study locations with raised hardened centerlines and medians have at least 11' of clearance between curbs.
- Parking zone delineation and adherence can cause challenges if vehicles are encroaching too close to the intersection – this can create a space that is too tight for vehicles driving to fit between the parked vehicle and the raised hardened centerline and therefore cause people to drive over the raised hardened centerline.

Figure 6: Damage on the raised hardened centerline at Fremont Ave N & 42nd Ave N

Figure 7: Remanent snow alongside raised hardened centerline after snow clearing

Summary of Findings

- Qualitative and quantitative data collected for this study demonstrate that the inclusion of vertical lane separation treatments at in-lane bus stops had a positive correlation on intersection safety both through the reduction of vehicle passing rates and a reduction in crashes.
- Video observations showed that intersections with raised hardened centerlines and medians at in-lane bus stops had a lower percentage of vehicles traveling into the oncoming traffic lane to pass buses stopped at transit stops. Locations with medians saw the lowest percentage of vehicle passing rates. Nearside stations and signalized intersections also saw lower percentages of vehicle passing rates than farside stations and stop controlled intersections, respectively.
- All study locations with vertical lane separation treatments saw a decrease in crash frequencies and crash rates after the installation of the raised hardened centerlines and medians. All study locations with a vertical lane separation treatment had overall lower crash rates than the control intersections.
- There was a higher compliance of pedestrians crossing in the crosswalks at study locations with raised hardened centerlines (80%) than at control locations (50%). A higher percentage of people were observed crossing in the crosswalk at nearside bus stops for both control (65%) and raised hardened centerline locations (11%) than at farside bus stop locations for control (36%) and raised hardened centerline locations (31%). No instances of tripping over the raised hardened centerline were observed during the video observations.
- Through public feedback received via 311 data and emails to City staff, the visibility of raised hardened centerlines can be challenging during winter months when snow builds up. This can create hazards for people walking and driving.
- Through City staff feedback and observations, the raised hardened centerlines have seen concrete damage due to snowplow blades running along or on top of the centerline causing chipping and scraping of the concrete.
- Lastly, there is variability in the design of the raised hardened centerlines across the study locations such as the length of the treatment and where it begins and ends at the intersection. Even with the design variability, all study locations meet current SDG guidance for this treatment type.

Staff Recommendations

Given the findings of this evaluation, staff recommend the following:

1. Continue the use of vertical lane separation treatments at in-lane bus stops; specifically medians.
    - Medians are the preferred design treatment at in-lane bus stops since they had lower vehicle passing rates, lower crash rates, no usability concerns raised from the public, and fewer maintenance concerns.
    - Raised hardened centerlines should no longer be used due to user safety concerns for people walking and driving.
        - Existing raised hardened centerlines along Fremont Ave N and Grand Ave S have been modified to include yellow paint along the top of the curb to help improve visibility. These locations should continue to be monitored.
2. In coordination with the Street Design Guide core team, update Street Design Guide language for medians and raised hardened centerlines at in-lane bus stops.
    - Remove language regarding raised hardened centerlines.
    - Provide additional design details for allowable median widths in constrained corridors.

Appendix A – SDG Language

The Minneapolis Street Design Guide (SDG) outlines design considerations for in-lane bus stops which includes the use of hardened centerlines and/or medians. The full SDG guidance can be found here and is summarized below.

Introduction

In-lane bus stops are where a transit vehicle stops to load and unload passengers in a through traffic lane. In-lane bus stops are preferred for bus rapid transit routes because they do not require the bus to merge back into traffic after making the stop, which is faster. They also can be beneficial for regular-route transit stops as they expand the available space for transit stop and sidewalk zone uses and allow for tighter, safer intersections. On streets with a single traffic lane in a direction, designers should work to mitigate the safety concerns of drivers passing a stopped bus.

Designers should discuss with Metro Transit and Traffic and Parking Services when determining if an in-lane bus stop is appropriate in an individual context. These factors should be considered:

- Traffic volumes, including annual daily traffic, peak hour traffic, directionality, and turning movements;
- Transit service, including frequency, directionality, stop spacing, stop consolidation, ridership volumes, where there is off-board far collections, and bus size; and
- Context, including number of traffic lanes, driveway access, loading zones, intersection control (stop, signal, RRFB), and cross-street modal networks.

Design Considerations

A. Lane widths – the lane where the bus stops should generally be the same width as the traffic lane leading up to the bus stop to discourage vehicles trying to pass the bus in the same lane
B. Curb extensions – if there is parking, curb extensions should be implemented with bus stop to align with the bus doors
C. Hardened centerlines and medians when stopping in sole traffic lane – a hardened centerline or median should be considered at an in-lane bus stop when a bus will be stopping in the sole traffic lane in a given direction. The hardened centerline or median is provided to reduce the likelihood that drivers will pass the bus.
    a. The hardened centerline should be 1’ wide.
    b. The median should be 4’ or wider when feasible to support a pedestrian safety island.
    c. The hardened centerline or median should generally be 20’ longer than the longest bus that will use the stop.
    d. Generally use 1:3 tapers; if a lane shift is involved, the taper needs to be evaluated further.
    e. The detailed design for hardened centerlines and medians adjacent to in-lane bus stops is being constructed on several upcoming projects in Minneapolis and will be evaluated to inform how they may evolve.

Appendix B – Vehicle Passing Rates

13-hour video data (6am – 7pm) was collected for each study location on 10/3/2023 or 10/4/2023 and was reviewed by City staff to observe user behaviors, specifically whether vehicles passed stopped buses or traffic at the bus stations.

Study Location	Station Location	Treament Type	Transit Route Type	Station Type	Stop Control	# Buses Stopped	# Buses Stopped + Vehicle Behind	# Vehicles Passing Stopped Vehicle (non-bus)	# Vehicles Passing Stopped Bus	Total # Vehicles Passing	% of Vehicles Passing Stopped Vehicle (non-bus)	% of Vehicles Passing Stopped Bus
Penn Ave & 36th Ave	southern	None (control)	BRT (C Line)	farside	none	66	76	2	32	34	6%	42%
	northern	None (control)	BRT (C Line)	farside	none	57	52	12	26	38	32%	50%
					TOTAL	**123**	**128**	**14**	**58**	**72**	**19%**	**45%**
Penn Ave & Dowling	southern	None (control) - bollard	BRT (C Line)	nearside	signalized	58	49	0	16	16	0%	33%
	northern	None (control) - bollard	BRT (C Line)	nearside	signalized	52	34	0	3	3	0%	9%
					TOTAL	**110**	**83**	**0**	**19**	**19**	**0%**	**23%**
Penn & Plymouth	southern	Median	BRT (C Line)	farside	signalized	69	57	0	5	5	0%	9%
	northern	Median	BRT (C Line)	farside	signalized	62	52	0	4	4	0%	8%
					TOTAL	**131**	**109**	**0**	**9**	**9**	**0%**	**8%**
Fremont & 35th Ave	southern	Hardened centerline	BRT (D Line)	farside	none	79	75	2	15	17	12%	20%
	northern	Hardened centerline	BRT (D Line)	farside	none	67	47	0	8	8	0%	17%
					TOTAL	**146**	**122**	**2**	**23**	**25**	**8%**	**19%**

Study Location	Station Location	Treament Type	Transit Route Type	Station Type	Stop Control	# Buses Stopped	# Buses Stopped + Vehicle Behind	# Vehicles Passing Stopped Vehicle (non-bus)	# Vehicles Passing Stopped Bus	Total # Vehicles Passing	% of Vehicles Passing Stopped Vehicle (non-bus)	% of Vehicles Passing Stopped Bus
Fremont & Dowling	southern	Hardened centerline	BRT (D Line)	farside	signalized	77	56	0	15	15	0%	27%
	northern	Hardened centerline	BRT (D Line)	farside	signalized	56	41	0	5	5	0%	12%
					TOTAL	**133**	**97**	**0**	**20**	**20**	**0%**	**21%**
Fremont & 42nd Ave	southern	Hardened centerline - bollard	BRT (D Line)	nearside	signalized	61	36	1	2	3	33%	6%
	northern	Hardened centerline - bollard	BRT (D Line)	nearside	signalized	57	24	1	0	1	100%	0%
					TOTAL	**118**	**60**	**2**	**2**	**4**	**50%**	**3%**
Grand Ave & 34th St W	southern	Hardened centerline	Limited Stop (113)	nearside	signalized	3	1	1	0	1	100%	0%
	northern	Hardened centerline	Limited Stop (113)	nearside	signalized	3	1	0	0	0	0%	0%
					TOTAL	**6**	**2**	**1**	**0**	**1**	**100%**	**0%**
Grand Ave & 43rd St W	southern	Median	Limited Stop (113)	nearside	none	1	0	0	0	0	0%	0%
	northern	Median	Limited Stop (113)	nearside	none	0	0	0	0	0	0%	0%
					TOTAL	**1**	**0**	**0**	**0**	**0**	**0%**	**0%**
Johnson St & 22nd Ave NE	southern	Median	Hi-frequency (Route 4)	nearside	RRFB	7	7	0	0	0	0%	0%
	northern	Median	Hi-frequency (Route 4)	nearside	RRFB	10	10	0	0	0	0%	0%
					TOTAL	**17**	**17**	**0**	**0**	**0**	**0%**	**0%**

Appendix C – Pedestrian Crossing Behaviors

13-hour video data (6am – 7pm) was collected for each study location with raised hardened centerlines on 10/3/2023 or 10/4/2023 and was reviewed by City staff to observe user behaviors, specifically whether pedestrians crossing at the intersection crossed in the crosswalk or over the raised hardened centerline. Data was unavailable between 6am-7am for the following two locations due to lack of lighting: Fremont Ave N & 35th Ave N and Fremont Ave N & 42nd Ave N. This is reflected in the tables below.

Penn Ave N & 36th Ave N

Time	Station location	Type of Movement				
		# of peds alighting from bus using crosswalk	# of peds alighting from bus crossing over centerline	# of other peds using crosswalk	# of other peds crossing over centerline	Total centerline crossings
6AM	South					
	North					
7AM	South	0	0	2	17	**17**
	North	0	0	4	3	**3**
8AM	South	0	0	4	12	**12**
	North	0	4	6	10	**14**
9AM	South	0	0	3	21	**21**
	North	4	1	3	10	**11**
10AM	South	0	0	2	5	**5**
	North	1	2	6	6	**8**
11AM	South	0	1	5	5	**6**
	North	0	2	3	2	**4**
12PM	South	1	0	1	8	**8**
	North	2	0	5	8	**8**
1PM	South	1	0	7	8	**8**
	North	0	1	4	17	**18**
2PM	South	0	2	5	6	**8**
	North	0	7	2	3	**10**
3PM	South	7	1	6	8	**9**
	North	3	1	3	3	**4**
4PM	South	0	1	8	10	**11**
	North	2	11	6	8	**19**
5PM	South	1	3	1	5	**8**
	North	1	7	14	10	**17**
6PM	South	0	0	3	16	**16**
	North	5	2	11	10	**12**
Total		**28**	**46**	**114**	**211**	**257**

Penn Ave N & Dowling Ave N

Time	Station location	Type of Movement				
		# of peds alighting from bus using crosswalk	# of peds alighting from bus crossing over centerline	# of other peds using crosswalk	# of other peds crossing over centerline	Total centerline crossings
6AM	South					
	North					
7AM	South	0	1	7	1	**2**
	North	0	0	5	1	**1**
8AM	South	2	0	1	1	**1**
	North	0	0	3	1	**1**
9AM	South	6	0	6	11	**11**
	North	0	0	1	1	**1**
10AM	South	0	0	5	1	**1**
	North	0	0	1	2	**2**
11AM	South	1	2	1	3	**5**
	North	0	0	0	0	**0**
12PM	South	1	0	2	1	**1**
	North	1	0	0	0	**0**
1PM	South	0	2	5	1	**3**
	North	1	0	0	2	**2**
2PM	South	1	0	6	5	**5**
	North	0	0	0	1	**1**
3PM	South	11	0	15	5	**5**
	North	0	0	2	0	**0**
4PM	South	3	1	1	2	**3**
	North	0	0	2	1	**1**
5PM	South	2	0	6	1	**1**
	North	0	0	1	2	**2**
6PM	South	2	2	7	4	**6**
	North	0	0	1	4	**4**
Total		**31**	**8**	**78**	**51**	**59**

Fremont Ave N & 35th Ave N

Time	Station location	Type of Movement				
		# of peds alighting from bus using crosswalk	# of peds alighting from bus crossing over centerline	# of other peds using crosswalk	# of other peds crossing over centerline	Total centerline crossings
6AM	South					
	North					
7AM	South	0	1	6	1	**2**
	North	0	0	2	0	**0**
8AM	South	0	0	3	0	**0**
	North	2	0	4	2	**2**
9AM	South	0	0	3	0	**0**
	North	0	1	0	0	**1**
10AM	South	3	0	7	1	**1**
	North	0	0	0	0	**0**
11AM	South	0	0	7	2	**2**
	North	1	0	2	1	**1**
12PM	South	0	1	6	1	**2**
	North	1	0	2	0	**0**
1PM	South	0	0	2	0	**0**
	North	1	2	1	1	**3**
2PM	South	1	0	5	1	**1**
	North	3	0	0	3	**3**
3PM	South	6	4	0	1	**5**
	North	6	2	1	0	**2**
4PM	South	0	1	4	4	**5**
	North	6	0	3	2	**2**
5PM	South	2	0	3	1	**1**
	North	4	2	3	2	**4**
6PM	South	1	0	1	2	**2**
	North	5	1	1	1	**2**
Total		**54**	**42**	**15**	**66**	**26**

Fremont Ave N & Dowling Ave N

Time	Station location	Type of Movement				
		# of peds alighting from bus using crosswalk	# of peds alighting from bus crossing over centerline	# of other peds using crosswalk	# of other peds crossing over centerline	Total centerline crossings
6AM	South	0	0	4	1	**1**
	North	0	0	0	0	**0**
7AM	South	1	4	6	0	**4**
	North	0	1	4	0	**1**
8AM	South	0	0	7	1	**1**
	North	2	2	6	4	**6**
9AM	South	0	0	5	1	**1**
	North	0	1	7	2	**3**
10AM	South	0	0	2	1	**1**
	North	0	0	4	1	**1**
11AM	South	0	0	1	0	**0**
	North	0	0	2	2	**2**
12PM	South	0	0	3	0	**0**
	North	1	3	6	5	**8**
1PM	South	1	0	2	1	**1**
	North	0	0	5	3	**3**
2PM	South	1	0	5	1	**1**
	North	0	0	7	0	**0**
3PM	South	3	0	4	2	**2**
	North	2	3	6	2	**5**
4PM	South	1	0	3	1	**1**
	North	0	3	1	0	**3**
5PM	South	0	0	2	0	**0**
	North	3	6	7	4	**10**
6PM	South	0	0	4	1	**1**
	North	1	3	3	2	**5**
Total		**54**	**16**	**26**	**106**	**35**

Fremont Ave N & 42nd Ave N

Time	Station location	Type of Movement				
		# of peds alighting from bus using crosswalk	# of peds alighting from bus crossing over centerline	# of other peds using crosswalk	# of other peds crossing over centerline	Total centerline crossings
6AM	South					
	North					
7AM	South	0	0	1	0	**0**
	North	0	0	6	0	**0**
8AM	South	0	3	10	6	**9**
	North	0	0	2	0	**0**
9AM	South	2	0	7	0	**0**
	North	2	0	6	3	**3**
10AM	South	1	0	4	2	**2**
	North	0	0	4	1	**1**
11AM	South	2	0	5	1	**1**
	North	2	0	1	1	**1**
12PM	South	0	0	6	0	**0**
	North	0	0	5	3	**3**
1PM	South	1	0	10	1	**1**
	North	1	0	5	0	**0**
2PM	South	6	0	4	1	**1**
	North	0	0	1	0	**0**
3PM	South	7	0	23	0	**0**
	North	1	0	11	1	**1**
4PM	South	8	0	15	2	**2**
	North	1	0	5	2	**2**
5PM	South	9	0	21	3	**3**
	North	2	0	2	1	**1**
6PM	South	4	0	26	2	**2**
	North	5	0	1	0	**0**
Total		**54**	**3**	**181**	**30**	**33**

Grand Ave S & W 34th St

Time	Station location	Type of Movement				
		# of peds alighting from bus using crosswalk	# of peds alighting from bus crossing over centerline	# of other peds using crosswalk	# of other peds crossing over centerline	Total centerline crossings
6AM	South	0	0	1	0	**0**
	North	0	0	1	0	**0**
7AM	South	0	0	6	1	**1**
	North	0	0	9	1	**1**
8AM	South	0	0	3	1	**1**
	North	0	0	34	0	**0**
9AM	South	0	0	7	0	**0**
	North	0	0	3	1	**1**
10AM	South	0	0	2	1	**1**
	North	0	0	6	0	**0**
11AM	South	0	0	1	2	**2**
	North	0	0	10	0	**0**
12PM	South	0	0	6	0	**0**
	North	0	0	9	0	**0**
1PM	South	0	0	5	0	**0**
	North	0	0	2	0	**0**
2PM	South	0	0	3	0	**0**
	North	2	0	9	3	**3**
3PM	South	0	0	2	0	**0**
	North	0	0	13	2	**2**
4PM	South	0	0	6	0	**0**
	North	0	0	5	0	**0**
5PM	South	0	0	7	1	**1**
	North	0	0	15	2	**2**
6PM	South	0	0	3	2	**2**
	North	0	0	8	1	**1**
Total		**54**	**2**	**0**	**176**	**18**

Appendix D – Crash Summaries

Crash summary data for each of the study locations - includes crash data from 1/1/2013 to 12/31/2023.

Control Intersections

Penn Ave & 36th Ave N

Crash Summary
Penn & 36th Ave

Crash Severity/Crash Year

Crash Severity	Total	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
K - Fatal	0	0	0	0	0	0	0	0	0	0	0
A - Serious Injury	4	0	0	0	0	0	1	0	0	2	1
B - Minor Injury	4	0	0	1	1	0	1	1	0	0	0
C - Possible Injury	17	2	1	1	3	0	2	1	4	2	1
N - Prop Dmg Only	37	4	4	3	5	7	4	6	3	0	1
Total	62	6	5	5	9	7	8	8	7	4	3

Crash Severity/Number of Vehicles

Crash Severity	Total	0	1	2	3+
K - Fatal	0	0	0	0	0
A - Serious Injury	4	0	3	1	0
B - Minor Injury	4	0	0	4	0
C - Possible Injury	17	0	2	12	3
N - Prop Dmg Only	37	0	3	30	4
Total	62	0	8	47	7

Basic Type Summary

	Total	%
Pedestrian	7	11.3
Bike	0	0.0
Single Vehicle Run Off Road	1	1.6
Single Vehicle Other	1	1.6
Sideswipe Same Direction	2	3.2
Sideswipe Opposing	0	0.0
Rear End	12	19.4
Head On	3	4.8
Left Turn	0	0.0
Angle	21	33.9
Other	15	24.2
Total	62	100.0

First Harmful Event Summary

	Total	%
Pedestrian	6	9.7
Bicyclist	0	0.0
Motor Vehicle In Transport	41	66.1
Parked Motor Vehicle	14	22.6
Train	0	0.0
Deer/Animal	0	0.0
Other - Non Fixed Object	0	0.0
Collision Fixed Object	1	1.6
Non-Collision Harmful Events	0	0.0
Other/Unknown	0	0.0
Total	62	100.0

Relationship to Intersection Summary

	Total	%
Not at Intersection/Interchange	22	35.5
Four-Way Intersection	34	54.8
T or Y Intersection	1	1.6
Five-Way Intersection or More	0	0.0
Roundabout	0	0.0
Intersection Related	1	1.6
Driveway Access Related	1	1.6
At School Crossing	0	0.0
Railway Grade Crossing	0	0.0
Shared Use Path or Trail	0	0.0
Interchange or Ramp	0	0.0
Crossover Related	0	0.0
Acceleration/Deceleration Lane	0	0.0
Other/Unknown	3	4.8
Total	62	100.0

Weather 1 Summary

	Total	%
Clear	45	72.6
Cloudy	9	14.5
Rain	4	6.5
Snow	3	4.8
Sleet, Hail (Freezing Rain/Drizzle)	0	0.0
Fog/Smog/Smoke	0	0.0
Blowing Sand/Soil/Dirt/Snow	0	0.0
Severe Crosswinds	0	0.0
Other/Unknown	1	1.6
Total	62	100.0

Light Condition Summary

	Total	%
Daylight	43	69.4
Sunrise	0	0.0
Sunset	2	3.2
Dark (Str Lights On)	17	27.4
Dark (Str Lights Off)	0	0.0
Dark (No Str Lights)	0	0.0
Dark (Unknown Light)	0	0.0
Other/Unknown	0	0.0
Total	62	100.0

Crash Summary
Penn & Dowling

Crash Severity/Crash Year

Crash Severity	Total	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
K - Fatal	0	0	0	0	0	0	0	0	0	0	0
A - Serious Injury	1	0	0	1	0	0	0	0	0	0	0
B - Minor Injury	10	1	1	3	1	0	1	2	0	1	0
C - Possible Injury	15	2	1	2	1	1	2	2	2	0	2
N - Prop Dmg Only	49	3	6	5	9	6	5	6	5	3	1
Total	75	6	8	11	11	7	8	10	7	4	3

Crash Severity/Number of Vehicles

Crash Severity	Total	0	1	2	3+
K - Fatal	0	0	0	0	0
A - Serious Injury	1	0	0	0	1
B - Minor Injury	10	0	1	7	2
C - Possible Injury	15	0	2	11	2
N - Prop Dmg Only	49	0	0	42	7
Total	75	0	3	60	12

Basic Type Summary

	Total	%
Pedestrian	1	1.3
Bike	0	0.0
Single Vehicle Run Off Road	0	0.0
Single Vehicle Other	2	2.7
Sideswipe Same Direction	5	6.7
Sideswipe Opposing	3	4.0
Rear End	19	25.3
Head On	7	9.3
Left Turn	3	4.0
Angle	25	33.3
Other	10	13.3
Total	75	100.0

First Harmful Event Summary

	Total	%
Pedestrian	1	1.3
Bicyclist	0	0.0
Motor Vehicle In Transport	67	89.3
Parked Motor Vehicle	4	5.3
Train	0	0.0
Deer/Animal	0	0.0
Other - Non Fixed Object	0	0.0
Collision Fixed Object	0	0.0
Non-Collision Harmful Events	1	1.3
Other/Unknown	2	2.7
Total	75	100.0

Relationship to Intersection Summary

	Total	%
Not at Intersection/Interchange	12	16.0
Four-Way Intersection	57	76.0
T or Y Intersection	1	1.3
Five-Way Intersection or More	0	0.0
Roundabout	0	0.0
Intersection Related	2	2.7
Driveway Access Related	1	1.3
At School Crossing	0	0.0
Railway Grade Crossing	0	0.0
Shared Use Path or Trail	0	0.0
Interchange or Ramp	0	0.0
Crossover Related	0	0.0
Acceleration/Deceleration Lane	0	0.0
Other/Unknown	2	2.7
Total	75	100.0

Weather 1 Summary

	Total	%
Clear	55	73.3
Cloudy	13	17.3
Rain	3	4.0
Snow	3	4.0
Sleet, Hail (Freezing Rain/Drizzle)	0	0.0
Fog/Smog/Smoke	0	0.0
Blowing Sand/Soil/Dirt/Snow	0	0.0
Severe Crosswinds	0	0.0
Other/Unknown	1	1.3
Total	75	100.0

Light Condition Summary

	Total	%
Daylight	49	65.3
Sunrise	0	0.0
Sunset	2	2.7
Dark (Str Lights On)	24	32.0
Dark (Str Lights Off)	0	0.0
Dark (No Str Lights)	0	0.0
Dark (Unknown Light)	0	0.0
Other/Unknown	0	0.0
Total	75	100.0

Treatment Intersections – Raised Hardened Centerline

Fremont Ave N & 35th Ave N

Crash Summary
Fremont & 35th Ave

Crash Severity/Crash Year

Crash Severity	Total	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
K - Fatal	0	0	0	0	0	0	0	0	0	0	0
A - Serious Injury	0	0	0	0	0	0	0	0	0	0	0
B - Minor Injury	0	0	0	0	0	0	0	0	0	0	0
C - Possible Injury	10	1	2	0	0	0	2	2	2	1	0
N - Prop Dmg Only	10	0	1	1	2	1	2	0	1	1	1
Total	20	1	3	1	2	1	4	2	3	2	1

Crash Severity/Number of Vehicles

Crash Severity	Total	0	1	2	3+
K - Fatal	0	0	0	0	0
A - Serious Injury	0	0	0	0	0
B - Minor Injury	0	0	0	0	0
C - Possible Injury	10	0	0	10	0
N - Prop Dmg Only	10	0	2	8	0
Total	20	0	2	18	0

Basic Type Summary	Total	%
Pedestrian	0	0.0
Bike	0	0.0
Single Vehicle Run Off Road	2	10.0
Single Vehicle Other	0	0.0
Sideswipe Same Direction	0	0.0
Sideswipe Opposing	1	5.0
Rear End	1	5.0
Head On	1	5.0
Left Turn	3	15.0
Angle	9	45.0
Other	3	15.0
Total	20	100.0

First Harmful Event Summary	Total	%
Pedestrian	0	0.0
Bicyclist	0	0.0
Motor Vehicle In Transport	16	80.0
Parked Motor Vehicle	2	10.0
Train	0	0.0
Deer/Animal	0	0.0
Other - Non Fixed Object	0	0.0
Collision Fixed Object	2	10.0
Non-Collision Harmful Events	0	0.0
Other/Unknown	0	0.0
Total	20	100.0

Relationship to Intersection Summary	Total	%
Not at Intersection/Interchange	5	25.0
Four-Way Intersection	15	75.0
T or Y Intersection	0	0.0
Five-Way Intersection or More	0	0.0
Roundabout	0	0.0
Intersection Related	0	0.0
Driveway Access Related	0	0.0
At School Crossing	0	0.0
Railway Grade Crossing	0	0.0
Shared Use Path or Trail	0	0.0
Interchange or Ramp	0	0.0
Crossover Related	0	0.0
Acceleration/Deceleration Lane	0	0.0
Other/Unknown	0	0.0
Total	20	100.0

Weather 1 Summary	Total	%
Clear	15	75.0
Cloudy	3	15.0
Rain	2	10.0
Snow	0	0.0
Sleet, Hail (Freezing Rain/Drizzle)	0	0.0
Fog/Smog/Smoke	0	0.0
Blowing Sand/Soil/Dirt/Snow	0	0.0
Severe Crosswinds	0	0.0
Other/Unknown	0	0.0
Total	20	100.0

Light Condition Summary	Total	%
Daylight	9	45.0
Sunrise	0	0.0
Sunset	0	0.0
Dark (Str Lights On)	11	55.0
Dark (Str Lights Off)	0	0.0
Dark (No Str Lights)	0	0.0
Dark (Unknown Light)	0	0.0
Other/Unknown	0	0.0
Total	20	100.0

Crash Summary
Fremont & Dowling

Crash Severity/Crash Year

Crash Severity	Total	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
K - Fatal	0	0	0	0	0	0	0	0	0	0	0
A - Serious Injury	2	0	0	0	0	1	0	1	0	0	0
B - Minor Injury	13	0	5	2	4	0	0	1	0	0	1
C - Possible Injury	15	4	1	2	2	0	2	1	1	0	2
N - Prop Dmg Only	29	2	3	3	5	7	4	1	1	3	0
Total	59	6	9	7	11	8	6	4	2	3	3

Crash Severity/Number of Vehicles

Crash Severity	Total	0	1	2	3+
K - Fatal	0	0	0	0	0
A - Serious Injury	2	0	0	0	2
B - Minor Injury	13	0	3	9	1
C - Possible Injury	15	0	0	13	2
N - Prop Dmg Only	29	0	1	27	1
Total	59	0	4	49	6

Basic Type Summary	Total	%
Pedestrian	4	6.8
Bike	0	0.0
Single Vehicle Run Off Road	0	0.0
Single Vehicle Other	1	1.7
Sideswipe Same Direction	4	6.8
Sideswipe Opposing	0	0.0
Rear End	16	27.1
Head On	1	1.7
Left Turn	4	6.8
Angle	23	39.0
Other	6	10.2
Total	59	100.0

First Harmful Event Summary	Total	%
Pedestrian	4	6.8
Bicyclist	0	0.0
Motor Vehicle In Transport	52	88.1
Parked Motor Vehicle	3	5.1
Train	0	0.0
Deer/Animal	0	0.0
Other - Non Fixed Object	0	0.0
Collision Fixed Object	0	0.0
Non-Collision Harmful Events	0	0.0
Other/Unknown	0	0.0
Total	59	100.0

Relationship to Intersection Summary	Total	%
Not at Intersection/Interchange	8	13.6
Four-Way Intersection	39	66.1
T or Y Intersection	0	0.0
Five-Way Intersection or More	0	0.0
Roundabout	0	0.0
Intersection Related	11	18.6
Driveway Access Related	0	0.0
At School Crossing	0	0.0
Railway Grade Crossing	0	0.0
Shared Use Path or Trail	0	0.0
Interchange or Ramp	0	0.0
Crossover Related	0	0.0
Acceleration/Deceleration Lane	0	0.0
Other/Unknown	1	1.7
Total	59	100.0

Weather 1 Summary	Total	%
Clear	40	67.8
Cloudy	7	11.9
Rain	4	6.8
Snow	5	8.5
Sleet, Hail (Freezing Rain/Drizzle)	1	1.7
Fog/Smog/Smoke	0	0.0
Blowing Sand/Soil/Dirt/Snow	0	0.0
Severe Crosswinds	0	0.0
Other/Unknown	2	3.4
Total	59	100.0

Light Condition Summary	Total	%
Daylight	37	62.7
Sunrise	0	0.0
Sunset	2	3.4
Dark (Str Lights On)	19	32.2
Dark (Str Lights Off)	0	0.0
Dark (No Str Lights)	0	0.0
Dark (Unknown Light)	1	1.7
Other/Unknown	0	0.0
Total	59	100.0

Crash Summary

Fremont & 42nd Ave

Crash Severity/Crash Year

Crash Severity	Total	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
K - Fatal	0	0	0	0	0	0	0	0	0	0	0
A - Serious Injury	1	0	0	0	0	0	0	0	1	0	0
B - Minor Injury	4	0	0	1	1	0	1	1	0	0	0
C - Possible Injury	10	3	0	2	1	1	1	0	0	1	1
N - Prop Dmg Only	12	1	2	2	2	1	0	2	1	0	1
Total	27	4	2	5	4	2	2	3	2	1	2

Crash Severity/Number of Vehicles

Crash Severity	Total	0	1	2	3+
K - Fatal	0	0	0	0	0
A - Serious Injury	1	0	0	1	0
B - Minor Injury	4	0	1	2	1
C - Possible Injury	10	0	2	6	2
N - Prop Dmg Only	12	0	0	12	0
Total	27	0	3	21	3

Basic Type Summary	Total	%
Pedestrian	2	7.4
Bike	1	3.7
Single Vehicle Run Off Road	0	0.0
Single Vehicle Other	0	0.0
Sideswipe Same Direction	2	7.4
Sideswipe Opposing	1	3.7
Rear End	3	11.1
Head On	1	3.7
Left Turn	4	14.8
Angle	8	29.6
Other	5	18.5
Total	27	100.0

First Harmful Event Summary	Total	%
Pedestrian	2	7.4
Bicyclist	1	3.7
Motor Vehicle In Transport	20	74.1
Parked Motor Vehicle	4	14.8
Train	0	0.0
Deer/Animal	0	0.0
Other - Non Fixed Object	0	0.0
Collision Fixed Object	0	0.0
Non-Collision Harmful Events	0	0.0
Other/Unknown	0	0.0
Total	27	100.0

Relationship to Intersection Summary	Total	%
Not at Intersection/Interchange	5	18.5
Four-Way Intersection	21	77.8
T or Y Intersection	0	0.0
Five-Way Intersection or More	0	0.0
Roundabout	0	0.0
Intersection Related	0	0.0
Driveway Access Related	1	3.7
At School Crossing	0	0.0
Railway Grade Crossing	0	0.0
Shared Use Path or Trail	0	0.0
Interchange or Ramp	0	0.0
Crossover Related	0	0.0
Acceleration/Deceleration Lane	0	0.0
Other/Unknown	0	0.0
Total	27	100.0

Weather 1 Summary	Total	%
Clear	18	66.7
Cloudy	5	18.5
Rain	3	11.1
Snow	0	0.0
Sleet, Hail (Freezing Rain/Drizzle)	1	3.7
Fog/Smog/Smoke	0	0.0
Blowing Sand/Soil/Dirt/Snow	0	0.0
Severe Crosswinds	0	0.0
Other/Unknown	0	0.0
Total	27	100.0

Light Condition Summary	Total	%
Daylight	14	51.9
Sunrise	0	0.0
Sunset	4	14.8
Dark (Str Lights On)	9	33.3
Dark (Str Lights Off)	0	0.0
Dark (No Str Lights)	0	0.0
Dark (Unknown Light)	0	0.0
Other/Unknown	0	0.0
Total	27	100.0

Crash Summary
Grand & 34th St W

Crash Severity/Crash Year

Crash Severity	Total	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
K - Fatal	0	0	0	0	0	0	0	0	0	0	0
A - Serious Injury	0	0	0	0	0	0	0	0	0	0	0
B - Minor Injury	0	0	0	0	0	0	0	0	0	0	0
C - Possible Injury	1	0	0	0	1	0	0	0	0	0	0
N - Prop Dmg Only	1	0	0	0	0	0	1	0	0	0	0
Total	2	0	0	0	1	0	1	0	0	0	0

Crash Severity/Number of Vehicles

Crash Severity	Total	0	1	2	3+
K - Fatal	0	0	0	0	0
A - Serious Injury	0	0	0	0	0
B - Minor Injury	0	0	0	0	0
C - Possible Injury	1	0	1	0	0
N - Prop Dmg Only	1	0	0	1	0
Total	2	0	1	1	0

Basic Type Summary

	Total	%
Pedestrian	0	0.0
Bike	0	0.0
Single Vehicle Run Off Road	1	50.0
Single Vehicle Other	0	0.0
Sideswipe Same Direction	0	0.0
Sideswipe Opposing	0	0.0
Rear End	0	0.0
Head On	0	0.0
Left Turn	0	0.0
Angle	0	0.0
Other	1	50.0
Total	2	100.0

First Harmful Event Summary

	Total	%
Pedestrian	0	0.0
Bicyclist	0	0.0
Motor Vehicle In Transport	0	0.0
Parked Motor Vehicle	1	50.0
Train	0	0.0
Deer/Animal	0	0.0
Other - Non Fixed Object	0	0.0
Collision Fixed Object	1	50.0
Non-Collision Harmful Events	0	0.0
Other/Unknown	0	0.0
Total	2	100.0

Relationship to Intersection Summary

	Total	%
Not at Intersection/Interchange	1	50.0
Four-Way Intersection	1	50.0
T or Y Intersection	0	0.0
Five-Way Intersection or More	0	0.0
Roundabout	0	0.0
Intersection Related	0	0.0
Driveway Access Related	0	0.0
At School Crossing	0	0.0
Railway Grade Crossing	0	0.0
Shared Use Path or Trail	0	0.0
Interchange or Ramp	0	0.0
Crossover Related	0	0.0
Acceleration/Deceleration Lane	0	0.0
Other/Unknown	0	0.0
Total	2	100.0

Weather 1 Summary

	Total	%
Clear	1	50.0
Cloudy	1	50.0
Rain	0	0.0
Snow	0	0.0
Sleet, Hail (Freezing Rain/Drizzle)	0	0.0
Fog/Smog/Smoke	0	0.0
Blowing Sand/Soil/Dirt/Snow	0	0.0
Severe Crosswinds	0	0.0
Other/Unknown	0	0.0
Total	2	100.0

Light Condition Summary

	Total	%
Daylight	1	50.0
Sunrise	0	0.0
Sunset	0	0.0
Dark (Str Lights On)	0	0.0
Dark (Str Lights Off)	0	0.0
Dark (No Str Lights)	0	0.0
Dark (Unknown Light)	1	50.0
Other/Unknown	0	0.0
Total	2	100.0

Crash Summary
Grand & 43rd St W

Crash Severity/Crash Year

Crash Severity	Total	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
K - Fatal	0	0	0	0	0	0	0	0	0	0	0
A - Serious Injury	0	0	0	0	0	0	0	0	0	0	0
B - Minor Injury	0	0	0	0	0	0	0	0	0	0	0
C - Possible Injury	0	0	0	0	0	0	0	0	0	0	0
N - Prop Dmg Only	3	0	0	0	1	0	1	1	0	0	0
Total	3	0	0	0	1	0	1	1	0	0	0

Crash Severity/Number of Vehicles

Crash Severity	Total	0	1	2	3+
K - Fatal	0	0	0	0	0
A - Serious Injury	0	0	0	0	0
B - Minor Injury	0	0	0	0	0
C - Possible Injury	0	0	0	0	0
N - Prop Dmg Only	3	0	0	3	0
Total	3	0	0	3	0

Basic Type Summary	Total	%
Pedestrian	0	0.0
Bike	0	0.0
Single Vehicle Run Off Road	0	0.0
Single Vehicle Other	0	0.0
Sideswipe Same Direction	0	0.0
Sideswipe Opposing	0	0.0
Rear End	0	0.0
Head On	0	0.0
Left Turn	0	0.0
Angle	3	100.0
Other	0	0.0
Total	3	100.0

First Harmful Event Summary	Total	%
Pedestrian	0	0.0
Bicyclist	0	0.0
Motor Vehicle In Transport	3	100.0
Parked Motor Vehicle	0	0.0
Train	0	0.0
Deer/Animal	0	0.0
Other - Non Fixed Object	0	0.0
Collision Fixed Object	0	0.0
Non-Collision Harmful Events	0	0.0
Other/Unknown	0	0.0
Total	3	100.0

Relationship to Intersection Summary	Total	%
Not at Intersection/Interchange	0	0.0
Four-Way Intersection	3	100.0
T or Y Intersection	0	0.0
Five-Way Intersection or More	0	0.0
Roundabout	0	0.0
Intersection Related	0	0.0
Driveway Access Related	0	0.0
At School Crossing	0	0.0
Railway Grade Crossing	0	0.0
Shared Use Path or Trail	0	0.0
Interchange or Ramp	0	0.0
Crossover Related	0	0.0
Acceleration/Deceleration Lane	0	0.0
Other/Unknown	0	0.0
Total	3	100.0

Weather 1 Summary	Total	%
Clear	2	66.7
Cloudy	1	33.3
Rain	0	0.0
Snow	0	0.0
Sleet, Hail (Freezing Rain/Drizzle)	0	0.0
Fog/Smog/Smoke	0	0.0
Blowing Sand/Soil/Dirt/Snow	0	0.0
Severe Crosswinds	0	0.0
Other/Unknown	0	0.0
Total	3	100.0

Light Condition Summary	Total	%
Daylight	1	33.3
Sunrise	0	0.0
Sunset	1	33.3
Dark (Str Lights On)	1	33.3
Dark (Str Lights Off)	0	0.0
Dark (No Str Lights)	0	0.0
Dark (Unknown Light)	0	0.0
Other/Unknown	0	0.0
Total	3	100.0

Treatment Intersections – Median

Penn Ave & Plymouth Ave N

Crash Summary

Penn & Plymouth

Crash Severity/Crash Year

Crash Severity	Total	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
K - Fatal	0	0	0	0	0	0	0	0	0	0	0
A - Serious Injury	1	0	0	0	1	0	0	0	0	0	0
B - Minor Injury	4	0	1	0	1	0	0	1	0	0	1
C - Possible Injury	11	4	1	2	1	0	1	0	1	0	1
N - Prop Dmg Only	41	6	3	8	8	0	6	5	1	3	1
Total	57	10	5	10	11	0	7	6	2	3	3

Crash Severity/Number of Vehicles

Crash Severity	Total	0	1	2	3+
K - Fatal	0	0	0	0	0
A - Serious Injury	1	0	1	0	0
B - Minor Injury	4	0	2	1	1
C - Possible Injury	11	0	3	7	1
N - Prop Dmg Only	41	0	5	34	2
Total	57	0	11	42	4

Basic Type Summary	Total	%
Pedestrian	3	5.3
Bike	0	0.0
Single Vehicle Run Off Road	7	12.3
Single Vehicle Other	1	1.8
Sideswipe Same Direction	5	8.8
Sideswipe Opposing	2	3.5
Rear End	19	33.3
Head On	4	7.0
Left Turn	3	5.3
Angle	10	17.5
Other	3	5.3
Total	57	100.0

First Harmful Event Summary	Total	%
Pedestrian	2	3.5
Bicyclist	0	0.0
Motor Vehicle In Transport	45	78.9
Parked Motor Vehicle	2	3.5
Train	0	0.0
Deer/Animal	0	0.0
Other - Non Fixed Object	1	1.8
Collision Fixed Object	7	12.3
Non-Collision Harmful Events	0	0.0
Other/Unknown	0	0.0
Total	57	100.0

Relationship to Intersection Summary	Total	%
Not at Intersection/Interchange	5	8.8
Four-Way Intersection	47	82.5
T or Y Intersection	0	0.0
Five-Way Intersection or More	0	0.0
Roundabout	0	0.0
Intersection Related	2	3.5
Driveway Access Related	0	0.0
At School Crossing	0	0.0
Railway Grade Crossing	0	0.0
Shared Use Path or Trail	0	0.0
Interchange or Ramp	0	0.0
Crossover Related	0	0.0
Acceleration/Deceleration Lane	0	0.0
Other/Unknown	3	5.3
Total	57	100.0

Weather 1 Summary	Total	%
Clear	36	63.2
Cloudy	13	22.8
Rain	6	10.5
Snow	2	3.5
Sleet, Hail (Freezing Rain/Drizzle)	0	0.0
Fog/Smog/Smoke	0	0.0
Blowing Sand/Soil/Dirt/Snow	0	0.0
Severe Crosswinds	0	0.0
Other/Unknown	0	0.0
Total	57	100.0

Light Condition Summary	Total	%
Daylight	38	66.7
Sunrise	3	5.3
Sunset	2	3.5
Dark (Str Lights On)	14	24.6
Dark (Str Lights Off)	0	0.0
Dark (No Str Lights)	0	0.0
Dark (Unknown Light)	0	0.0
Other/Unknown	0	0.0
Total	57	100.0

Crash Summary

Johnson & 22nd Ave NE

Crash Severity/Crash Year

Crash Severity	Total	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
K - Fatal	0	0	0	0	0	0	0	0	0	0	0
A - Serious Injury	2	0	2	0	0	0	0	0	0	0	0
B - Minor Injury	2	0	0	0	0	0	1	0	1	0	0
C - Possible Injury	3	0	1	0	1	1	0	0	0	0	0
N - Prop Dmg Only	10	1	2	0	2	2	1	0	1	0	1
Total	17	1	5	0	3	3	2	0	2	0	1

Crash Severity/Number of Vehicles

Crash Severity	Total	0	1	2	3+
K - Fatal	0	0	0	0	0
A - Serious Injury	2	0	1	1	0
B - Minor Injury	2	0	0	1	1
C - Possible Injury	3	0	0	1	2
N - Prop Dmg Only	10	0	1	6	3
Total	17	0	2	9	6

Basic Type Summary

Basic Type Summary	Total	%
Pedestrian	1	5.9
Bike	0	0.0
Single Vehicle Run Off Road	1	5.9
Single Vehicle Other	0	0.0
Sideswipe Same Direction	0	0.0
Sideswipe Opposing	2	11.8
Rear End	9	52.9
Head On	0	0.0
Left Turn	1	5.9
Angle	2	11.8
Other	1	5.9
Total	17	100.0

First Harmful Event Summary

First Harmful Event Summary	Total	%
Pedestrian	1	5.9
Bicyclist	0	0.0
Motor Vehicle In Transport	13	76.5
Parked Motor Vehicle	2	11.8
Train	0	0.0
Deer/Animal	0	0.0
Other - Non Fixed Object	0	0.0
Collision Fixed Object	1	5.9
Non-Collision Harmful Events	0	0.0
Other/Unknown	0	0.0
Total	17	100.0

Relationship to Intersection Summary

Relationship to Intersection Summary	Total	%
Not at Intersection/Interchange	6	35.3
Four-Way Intersection	9	52.9
T or Y Intersection	0	0.0
Five-Way Intersection or More	0	0.0
Roundabout	0	0.0
Intersection Related	1	5.9
Driveway Access Related	0	0.0
At School Crossing	0	0.0
Railway Grade Crossing	0	0.0
Shared Use Path or Trail	0	0.0
Interchange or Ramp	0	0.0
Crossover Related	0	0.0
Acceleration/Deceleration Lane	0	0.0
Other/Unknown	1	5.9
Total	17	100.0

Weather 1 Summary

Weather 1 Summary	Total	%
Clear	15	88.2
Cloudy	2	11.8
Rain	0	0.0
Snow	0	0.0
Sleet, Hail (Freezing Rain/Drizzle)	0	0.0
Fog/Smog/Smoke	0	0.0
Blowing Sand/Soil/Dirt/Snow	0	0.0
Severe Crosswinds	0	0.0
Other/Unknown	0	0.0
Total	17	100.0

Light Condition Summary

Light Condition Summary	Total	%
Daylight	13	76.5
Sunrise	0	0.0
Sunset	1	5.9
Dark (Str Lights On)	3	17.6
Dark (Str Lights Off)	0	0.0
Dark (No Str Lights)	0	0.0
Dark (Unknown Light)	0	0.0
Other/Unknown	0	0.0
Total	17	100.0

Appendix E – Crash Rates

Before and after crash rates were calculated for each of the study locations using the data below.

Treatment Type	Study Location	Before				After			
		C – Total Number of Intersection Crashes in Study Period	N – Number of Years of Data	V – Daily Intersection Traffic Volumes	Crash Rate	C – Total Number of Intersection Crashes in Study Period	N – Number of Years of Data	V – Daily Intersection Traffic Volumes	Crash Rate
Control (no-treatment)	Penn Ave N & 36th Ave N	19	3	9,200	1.89	19	3	9,200	1.89
	Penn Ave N & Dowling Ave N	30	3	14,852	1.84	20	3	14,852	1.23
Raised hardened centerline	Fremont Ave N & 35th Ave N	6	2	3,360	2.45	3	2	3,360	1.22
	Fremont Ave N & Dowling Ave N	10	2	13,000	1.05	6	2	13,000	0.63
	Fremont Ave N & 42nd Ave N	5	2	7,000	0.98	3	2	7,000	0.59
	Grand Ave S & 34th St W	1	2	3,078	0.45	0	2	3,078	0.00
Median	Grand Ave S & 43rd St W	2	2	3,078	0.89	0	2	3,078	0.00
	Penn Ave N & Plymouth Ave N	8	2	11,736	0.93	6	2	11,736	0.70
	Johnson St NE & 22nd Ave NE	2	2	12,600	0.22	1	2	12,600	0.11