DEPARTMENT OF TRANSPORTATION

Multi-city study of an engineering and outreach program to increase driver yielding at signalized and unsignalized crosswalks

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16. Abstract (Limit: 250 words)

Pedestrian deaths are at a 30-year high nationally, accounting for 16% of total deaths in 2018 and far exceeding the previous decade of 12%, a trend mirrored in Minnesota. Previous research found an increase in local and citywide yielding at unsignalized crosswalks following an engineering and high-visibility enforcement program in Saint Paul, Minnesota. This study examined a modified engineering-focused (i.e., without enforcement) program expanded to both unsignalized and signalized intersections across the Twin Cities. The six-month study found modest improvements in yielding from baseline to treatment end (48.1% to 65.5% in Saint Paul and 19.8% to 38.8% in Minneapolis) at unsignalized engineering treatment sites but no improvements at generalization sites. No significant improvements in left- or right-turning yielding by drivers in Saint Paul were found at treated signalized intersections, but given that yielding was significantly worse at generalization sites over time, there may be some evidence that treatments mitigated performance declines among Saint Paul drivers during the study period. Yielding improvements at signalized treatment sites were more pronounced for only right-turning drivers in Minneapolis, but generalization sites showed no improvement or even worsened over time. Overall, study results suggested no shift in driving culture in either city, as found with the previous study using police enforcement, but found some evidence of local, site-specific changes in driver yielding behavior at treatment locations.

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Multi-city study of an engineering and outreach program to increase driver yielding at signalized and unsignalized crosswalks

FINAL REPORT

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LIST OF ABBREVIATIONS

CI: Confidence Intervals

DID: Differences-in-Difference

GEE: Generalized Estimating Equations

HVE: High-Visibility Enforcement

LPI: Leading Pedestrian Interval

M: Mean

MnDOT: Minnesota Department of Transportation

PPLT: Protected-Permitted Left-Turn

PSA: Public Safety Announcement

R1-6: In-street Pedestrian Crossing Stop Sign

RR: Risk Ratio

RRR: Relative Risk Ratio

SD: Standard Deviation

SPPD: Saint Paul Police Department

EXECUTIVE SUMMARY

Pedestrian deaths are at a 30-year high nationally, accounting for 16% of total deaths in 2018 and far exceeding the previous decade of 12%, a trend mirrored in Minnesota. Addressing the growing rates of pedestrian crashes is key to meeting Minnesota's Toward Zero Deaths goals and critical to supporting healthy, livable communities. A 2018 study supported by MnDOT demonstrated that a multifaceted approach of education, high-visibility enforcement (HVE), and engineering (i.e., enhanced Stop For Me program) in Saint Paul resulted in improved yielding rates and reduced multiple threat passing citywide (Morris et al., 2019). The study demonstrated how other communities across the state can maximize efforts to address driver yielding at unsignalized, marked crosswalks. The 2018 study did not examine driver yielding at signalized intersections and could not disentangle the impact of HVE from engineering.

This study examined a modified engineering-focused (i.e., without enforcement) program expanded to both unsignalized and signalized intersections across the Twin Cities. The aims of this study were to analyze the effectiveness of previous and newly implemented countermeasures to improve driver yielding to pedestrians at signalized intersections, investigate the strength of engineering improvements with and without HVE, and compare the feasibility of the treatment and strength of performance to previous work at unsignalized intersections.

The study consisted of a 26-week field data collection period from April 30, 2021, to November 19, 2021, to record drivers' yielding performance toward pedestrians at both unsignalized and signalized intersections in Saint Paul and Minneapolis. As part of the program, initiatives for enhancing the entire pedestrian safety culture, blue community feedback signs that provided up-to-date messages on the observed weekly yielding percent, were posted across different major corridors in both cities. The installation dates of these feedback signs began during the third week of July 2021 (i.e., data collection week 11) in both cities. Any data collection period before the feedback signs was carefully examined to determine relevant baseline periods for later comparisons.

Due to different intervention deployment strategies applied by each city, the intervention type and implementation time varied from one intersection to another. For unsignalized intersections, selected types of engineering countermeasures included temporary bump-outs and pedestrian refuges, as well as in-street R1-6 signs indicating that drivers should stop for pedestrians at the crosswalk. For signalized intersections, engineering countermeasures included installation of leading pedestrian intervals (LPIs), hardened centerlines, or signage indicating that turning drivers should stop for pedestrians. Stop bars, repainted crosswalks, and 4-3 lane conversions were applied at both signalized and unsignalized intersections. The first implementation of any engineering countermeasure was observed during the week of July 21, 2021 (i.e., week 10 of data collection), in both Saint Paul and Minneapolis. All remaining intervention strategies were deployed within 2 to 3 stages in sequential order (i.e., within data collection weeks 16-26) until late-September in Saint Paul and mid-October 2021 in Minneapolis.

The study results found modest improvements in yielding at engineering treatment sites but no improvements at generalization sites (i.e., sites that received no treatment). More specifically, driver yielding at unsignalized treatment sites in Saint Paul and Minneapolis significantly increased from baseline measurements of 48.1% and 19.8%, respectively, to 65.5% (i.e., excluding Snelling and Laurel) and 38.8%, respectively, following program implementation. However, unsignalized generalization site performance in both Saint Paul and Minneapolis slightly decreased from 35.1% and 26%, respectively, to 31.4% and 24.9%, respectively. Consistent with the previous study's findings, single and multiple R1-6 signs appeared to improve yielding to pedestrians at unsignalized crosswalks. The current study also found that selected temporary pedestrian infrastructure (e.g., flexible bollard posts for temporary bump-outs and refuge islands) resulted in improved driver yielding to pedestrians. Additionally, adding markings to unmarked, unsignalized crosswalks improved driver yielding but should be cautiously considered in the absence of other treatments on multilane, high-speed roadways.

Changes at signalized intersections in both Saint Paul and Minneapolis were more modest following treatment. No significant improvements in left or right-turning yielding by drivers in Saint Paul were found at treated signalized intersections, but given that yielding was significantly worse at generalization sites over time, there could be some evidence that treatments mitigated performance declines among Saint Paul drivers during the study period. Yielding improvements were more pronounced by only right-turning drivers in Minneapolis at signalized treatment sites, but generalization sites found no improvement or even worsened over time. For signalized marked crossings, the impact of the interventions such as leading pedestrian intervals (LPIs), right-turn stop for pedestrian signs, and hardened centerlines have a larger effect on right-turning yielding propensity relative to left-turning yielding propensity. If right-turning yielding is the primary driver behavior of concern, these measures may be effective, but if left-turning yielding is the primary behavior of concern, other interventions may be more appropriate.

Overall, study results suggested no shift in driving culture in either city as a result of this engineering-focused program, as found with the previous study that included using police enforcement but did find some evidence of local, site-specific changes in driver-yielding behavior at treatment locations. There are a number of confounds between the 2018 study and the current study that complicate their comparison beyond simply considering methodological differences between the studies, such as the absence of police enforcement at unsignalized intersections. Confound considerations include strained community-police relations, COVID-19, construction, citywide speed limits, and seasonal/time/weather differences. These confounds may have exacerbated risky driving behaviors, making engineering treatments less successful and may have limited media engagement and resultant uptake of the outreach messaging due to competing topics related to public safety.

Given the final results, the study recommendations include: 1) using a program of this kind (i.e., engineering and outreach without police enforcement) for local treatment rather than attempting citywide, driving culture treatment, 2) treating low-speed, 2-3 lane unsignalized crosswalks with single or multiple R1-6 signs or temporary bollards for curb extensions or refuge islands, as well as crosswalk marking to improve yielding to pedestrians at these crosswalks, 3) treating signalized intersections with LPIs to improve turning-driver yielding to pedestrians, and 4) using feedback signs only when yielding behaviors are near or above 50% and in conjunction with other phased treatments to increase numbers.

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Pedestrian deaths are at a 30-year high nationally, accounting for 16% of total deaths in 2018 and far exceeding the previous decade of 12%, a trend mirrored in Minnesota. From 2009 to 2018, there has been an average of 39.4 pedestrian fatalities per year for the entire state of Minnesota. Conservative estimates indicate that serious injuries from pedestrian-vehicle crashes will result in lifetime financial losses of $791,751 per case (Miller et al., 2004). Fatalities are estimated to cost society $4,538,000 per death (Xie, Ozbay, Kurkcu, & Yang, 2017), meaning the past decade's fatal pedestrian crashes will cumulatively cost Minnesota society approximately $1.8 billion. The impact these deaths have on Minnesota families is immeasurable. Rising pedestrian volumes are expected across the state, in walkable and non-walkable communities alike, and the increasing conflicts with motor vehicles must be addressed. Addressing the growing rates of pedestrian crashes is key to meeting Minnesota's Toward Zero Deaths goals and critical to supporting healthy, livable communities.

A 2018 study supported by MnDOT evaluated a multifaceted approach of education, high-visibility enforcement (HVE), and engineering (i.e., enhanced Stope for Me program) in Saint Paul, Minnesota (Morris et al., 2019). The results of the 2018 Saint Paul study showed that drivers yielded to pedestrians at unsignalized, marked crosswalks only 32% of the time during baseline data collection periods, but following the multifaceted intervention (i.e., education, engineering, and enforcement) driver yielding increased to as high as 78% at enforcement sites and 61% at untreated, generalization sites. Multiple threat passing was also reduced from approximately 11% of every crossing to approximately 3% of every crossing. Overall, the study found evidence that driving culture in Saint Paul changed to be one that is more likely to stop for pedestrians at marked, unsignalized crosswalks even where no local treatment has been applied. The 2018 study did not examine driver yielding at signalized intersections and it could not disentangle the impact of HVE from engineering. Given the high incidences of pedestrians struck and killed by turning drivers at signalized intersections, it is imperative to determine whether a similar program could be applied to signalized intersections. Furthermore, given the ongoing public dialog about the role of police enforcement in traffic safety, as well as a limited number of comparable Stop For Me programs nationally and a paucity of research regarding their efficacy, it is valuable to explore whether a similar but engineering-focused program (i.e., without police enforcement) could achieve a similar shift in driving culture to support pedestrian yielding at crosswalks.

This study examined a modified engineering-focused (i.e., without enforcement) program expanded to both unsignalized and signalized intersections across the Twin Cities. The aims of the study were to:

1) Analyze the effectiveness of previous and newly implemented countermeasures to improve driver yielding to pedestrians at signalized intersections,
2) Investigate the strength of engineering improvements with and without HVE, and
3) Compare the feasibility of the treatment and strength of performance to previous work at unsignalized intersections.

1.2 LITERATURE REVIEW

The present study is novel in that it targets both unsignalized and signalized intersections across two major adjacent cities. Prior to site selection, the research literature on high-visibility enforcement (HVE) and pedestrian safety at unsignalized intersections was updated from a prior review by the authors (Morris, Craig, & Van Houten, 2019), and the authors also provide a summary of research on pedestrian safety at signalized intersections. Associated topics (e.g., speeding) were also considered. Following the literature review is a description of site selection for intervention across the two cities, the process of selection, and a finalized list of sites that would receive measurement and intervention.

In addition to the effectiveness of HVE, the effectiveness of pedestrian crash countermeasures has been reviewed by Blackburn, Zegeer, and Brookshire (2018). The summaries of these countermeasures and where they are best applied are provided in Figure 1.1 and Figure 1.2.

	Posted Speed Limit and AADT								
	Vehicle AADT <9,000			Vehicle AADT 9,000–15,000			Vehicle AADT >15,000		
Roadway Configuration	≤30 mph	35 mph	≥40 mph	≤30 mph	35 mph	≥40 mph	≤30 mph	35 mph	≥40 mph
2 lanes (1 lane in each direction)	❶ 2 4 5 6	❶ 5 6 7 9	① 5 6 ❼ ❾	❶ 4 5 6	❶ 5 6 7 9	① 5 6 ❼ ❾	❶ 4 5 6 7 9	① 5 6 7 9	① 5 6 ❾
3 lanes with raised median (1 lane in each direction)	❶ 2 3 4 5	❶ ❸ 5 7 9	① ❸ 5 ❼ ❾	① 3 4 5 7 9	① ❸ 5 ❼ ❾	① ❸ 5 ❼ ❾	① ❸ 4 5 7 9	① ❸ 5 ❼ ❾	① ❸ 5 ❾
3 lanes w/o raised median (1 lane in each direction with a two-way left-turn lane)	❶ 2 3 4 5 6 7 9	❶ ❸ 5 6 7 9	① ❸ 5 6 ❾	① 3 4 5 6 7 9	① ❸ 5 6 ❼ ❾	① ❸ 5 6 ❾	① ❸ 4 5 6 7 9	① ❸ 5 6 ❾	① ❸ 5 6 ❾
4+ lanes with raised median (2 or more lanes in each direction)	❶ ❸ 5 7 8 9	❶ ❸ 5 7 8 9	① ❸ 5 8 ❾	① ❸ 5 7 8 9	① ❸ 5 ❼ 8 ❾	① ❸ 5 8 ❾	① ❸ 5 ❼ 8 ❾	① ❸ 5 8 ❾	① ❸ 5 8 ❾
4+ lanes w/o raised median (2 or more lanes in each direction)	❶ ❸ 5 6 7 8 9	① ❸ 5 ❻ 7 8 9	① ❸ 5 ❻ 8 ❾	① ❸ 5 ❻ 7 8 9	① ❸ 5 ❻ ❼ 8 ❾	① ❸ 5 ❻ 8 ❾	① ❸ 5 ❻ ❼ 8 ❾	① ❸ 5 ❻ 8 ❾	① ❸ 5 ❻ 8 ❾

Given the set of conditions in a cell,

- # Signifies that the countermeasure is a candidate treatment at a marked uncontrolled crossing location.
- ● Signifies that the countermeasure should always be considered, but not mandated or required, based upon engineering judgment at a marked uncontrolled crossing location.
- ○ Signifies that crosswalk visibility enhancements should always occur in conjunction with other identified countermeasures.*

The absence of a number signifies that the countermeasure is generally not an appropriate treatment, but exceptions may be considered following engineering judgment.

1. High-visibility crosswalk markings, parking restrictions on crosswalk approach, adequate nighttime lighting levels, and crossing warning signs
2. Raised crosswalk
3. Advance Yield Here To (Stop Here For) Pedestrians sign and yield (stop) line
4. In-Street Pedestrian Crossing sign
5. Curb extension
6. Pedestrian refuge island
7. Rectangular Rapid-Flashing Beacon (RRFB)**
8. Road Diet
9. Pedestrian Hybrid Beacon (PHB)**

Figure 1.1 Pedestrian crash countermeasures, taken from Blackburn, Zegeer, and Brookshire (2018).

Pedestrian Crash Countermeasure for Uncontrolled Crossings	Safety Issue Addressed: Conflicts at crossing locations	Excessive vehicle speed	Inadequate conspicuity/ visibility	Drivers not yielding to pedestrians in crosswalks	Insufficient separation from traffic
Crosswalk visibility enhancement	🚶	🚶	🚶	🚶	🚶
High-visibility crosswalk markings*	🚶		🚶	🚶	
Parking restriction on crosswalk approach*	🚶		🚶	🚶	
Improved nighttime lighting*	🚶		🚶		
Advance Yield Here To (Stop Here For) Pedestrians sign and yield (stop) line*	🚶		🚶	🚶	🚶
In-Street Pedestrian Crossing sign*	🚶	🚶	🚶	🚶	
Curb extension*	🚶	🚶	🚶		🚶
Raised crosswalk	🚶	🚶	🚶	🚶	
Pedestrian refuge island	🚶	🚶	🚶		🚶
Pedestrian Hybrid Beacon	🚶	🚶	🚶	🚶	
Road Diet	🚶	🚶	🚶		🚶
Rectangular Rapid-Flashing Beacon	🚶		🚶	🚶	🚶

*These countermeasures make up the STEP countermeasure "crosswalk visibility enhancements." Multiple countermeasures may be implemented at a location as part of crosswalk visibility enhancements.

Figure 1.2 Safety issues addressed, taken from Blackburn, Zegeer, and Brookshire (2018).

1.2.1 Unsignalized Intersections

Considering the immediate question of a high-visibility enforcement (HVE) program targeting unsignalized intersections, Craig, Morris, Van Houten, and Mayou (2019) and Morris, Craig and Van Houten (2020) performed a more detailed analysis of the data summarized within the report by Morris, Craig, and Van Houten (2019) which focused on an HVE program in Saint Paul, Minnesota from Fall 2017 to Fall 2018. Craig and colleagues (2019) found that the initial phases of high-visibility enforcement, without engineering measures such as R1-6 signs or community feedback signs, had a significant impact on public transport vehicles (e.g., buses), pushing public transport compliance with pedestrian stopping laws at a crosswalk close to 90%. Furthermore, there appears to be a negative effect on general overall compliance with the stopping law when a marked crosswalk is close in proximity to a near-side bus stop, perhaps reflecting confusion on the part of drivers on whether the pedestrian intends to cross or is waiting for a bus. Drivers are not out of compliance if the pedestrian has not stepped into the road, but given the proximity to the bus stop, drivers may not be anticipating that a nearby pedestrian will step into the crosswalk. In terms of placement of crosswalks and bus stops, Hosford, Tremblay, and Winters (2020) considered the frequency of crosswalk markings near bus stops in Vancouver and found that unmarked crosswalks were more frequent at bus stops near higher income neighborhoods relative to bus stops in lower income neighborhoods. However, this may be due to reduced public transportation and pedestrian traffic volume in higher income neighborhoods.

Morris and colleagues (2020) conducted a more detailed analysis on the completed HVE program in Saint Paul and found that the initial phases of the program were significantly effective at reducing multiple threat passing rates, which was a problem in the baseline measurement phase of the study. This reduction may have been, in part, spurred by a change in Saint Paul Police Department's policy to issue an enhanced citation for "Endangering life or public property" which required the driver to address the citation in court rather than simply pay the fine and this change was widely publicized through earned publicity with local news agencies. Furthermore, Morris and colleagues (2020) observed that the presence of advance stop lines had a significant effect on improving stopping compliance to staged crossings at marked unsignalized crosswalks.

Mirroring the findings of the benefits of advance stop lines, Zeeger and colleagues (2017) found a 25% reduction in pedestrian crash risk for crossing locations with advance stop lines. Other investigated treatments that led to reduced pedestrian crash risk included pedestrian hybrid beacons (55% reduction), rectangular rapid-flashing beacons (47% reduction) and refuge islands (32% reduction). Sarwar and colleagues (2017) also found that high-visibility crosswalks (HVCs), which are characterized by pavement marking styles (textured pavement, zebra/ladder markings) which are designed to improve crosswalk visibility for drivers (relative to no crosswalk or transverse lines), lead to safer driver behaviors after installation of the HVC when considering naturalistic driving measures.

Furthermore, Morris and colleagues (2020) observed a significant improvement in stopping compliance with the implementation of engineering measures designed to improve stopping, such as R1-6 signs and gateway installations of the R1-6 signs. Furthermore, advance stop lines were also demonstrated to improve stopping rates when they were present at crosswalks. Bennet and Van Houten (2016) found that while in-street signs with messages not present (e.g., blank) improved stopping compliance somewhat, when signs had messages, stopping percentages greatly improved. Moreover, in-street signs arranged in "full gateways" (in-street signs at each roadway edge and lane lane) were more effective than partial gateway treatments. Hochmuth and Van Houten (2018) targeted advance placement of gateways, which are multiple in-street signs placed in a spaced manner designed to simulate a gate. They found that gateways not only improved stopping compliance, but that gateways placed at advanced locations notably improved yielding distance (e.g., 50ft or more), which is important for providing sight distance on multilane roads. Hochmuth, Crowley-Koch, and Van Houten (2020) found that gateway treatments at one crosswalk improved yielding rates at an untreated adjacent crosswalk, suggesting some spillover effect, although the improvement in yielding rates at the untreated crosswalk wasn't as strong compared to the treated site.

1.2.1.1 Risk factors

Considering risk factors and crash prediction models, Kitali and colleagues (2017) found that their model, drawn from epidemiological research, showed that six factors predicted fatal and severe injuries for older pedestrians: age (older is worse), alcohol use, the nature of the initial harmful event, the type of vehicle movement (straight is worse than turn), the shoulder type present (no shoulder/flat is worse), and the posted speed limit (higher is worse). Another study developed a method to assign or score unsignalized intersections for risk, using features of the intersection to define an intersection's "safety index". For pedestrian risk at urban unsignalized intersections, the simplified criteria comprised of pedestrian sight distance (e.g., how well pedestrians can see vehicles before and during crossing obstacles), the presence of markings and signs (missing/faded), location (inconsistent with road design), and accessibility (Montella, Guida, Mosca, Lee, & Abdel-Aty, 2020). Further, pedestrian-involved crash risks dramatically increase during nighttime conditions due to reduced visual function among drivers (Wood, 2020) and poor lighting of the road segments (Zhou & Hsu, 2009).

Lindsey and colleagues (2019) used pedestrian and bicycle crash data from Minneapolis, Minnesota to clarify how crash risk was distributed through the city. The primary set of findings indicated that pedestrian and bicycle crash risk at both intersections and mid-block was associated with exposure to risk, and that when controlling for central business districts, there were significant disparities in risk through the city, with higher risk at intersections in lower-income areas with largely minority populations.

1.2.1.2 Speed factors

The speed of vehicles and posted speeds are factors that contribute to pedestrian crash risk and the severity of crash. Papić and colleagues (2020) found that pedestrian participants underestimated the speed of oncoming vehicles when standing on the side of the road. When there was only one vehicle, underestimation was more severe for vehicles traveling more than ~30 mph (50 k/h). When there were two vehicles that the pedestrian had to judge, more severe underestimations were made of vehicles driving under 30 mph, and the underestimation was greater for the slower of the two vehicles. Taken together, when pedestrians choose to cross, they may not accurately gauge the speed of oncoming vehicles, increasing the risk of a crash.

Furthermore, faster vehicle speeds (as measured by 85th percentile speeds on roadways) were shown to lead to less yielding to pedestrians engaging in staged crossing maneuvers, showing that speed and high-speed roadways are associated with lower yield rates to pedestrians (Bertulis & Dulaski, 2014). Additionally, a driving simulation experiment measuring driving scenario variables on driver yielding to simulated pedestrians found that lower approach speed, no curb-side parking and higher number of pedestrians crossing, led to an increased likelihood of drivers yielding (Obeid, Abkarian, Abou-Zeid, & Kaysi, 2017).

To test measures designed to reduce driver speeds in a driving simulation, Bella and Silvestri (2015) tested curb extensions, parking restrictions, and advance stop lines to see what impact this had on driver speeds towards a zebra crossing with simulated pedestrians present or absent. They observed that the most effective countermeasure was curb extensions. Bella and Silvestri (2016) further analyzed speed reduction time with a new model and found that this speed reduction was only significantly reduced by curb extensions (compared to the other two interventions) when a pedestrian was present and thus argued that curb extensions allow for improved visibility of pedestrians and allow for adaptation of approach speed instead of having to engage in abrupt maneuvers (e.g., hard braking).

Vingali and colleagues (2019) considered a similar problem with vehicle speeds at zebra crossings and considered the effects of median refuge islands and flashing vertical signs with a before-after analysis, measuring both speed and visual gaze location and duration with eyewear. The introduction of the interventions increased overall gaze percentage on elements of the crosswalk, and overall gaze time on the crosswalk itself. Furthermore, approach speed was reduced after the intervention was implemented as well, although the effect size was small.

1.2.2 Signalized Intersections

While the previous section focused on updating Morris, Craig, and Van Houten (2019) on the known literature on pedestrian safety at unsignalized intersections, this section comprises a robust description of research on pedestrian safety at signalized intersections. This topic is covered in a timeline approach, with older research summarized first, and the latest research described last.

Palamarthy, Mahmassani, and Machemehl (1994) assessed gap acceptance behavior for pedestrians at signalized intersections. Pedestrian crossing decisions primarily relied on perceived gap size, along with the presence of other pedestrians crossing as a group, and the busyness of the intersection. Furthermore, pedestrians did not cross “lane by lane”, but were more likely to look for one large overall gap in traffic.

Retting, Van Houten, Malenfant, Van Houten, and Farmer (1996) evaluated the safety contribution of pavement and sign markings to reduce the likelihood of pedestrian strikes by turning vehicles, particularly considering whether these interventions lead to increases in pedestrians checking for turning vehicles. Either prompt led to improvements in pedestrians looking for these vehicles, but both together had the best impact. Furthermore, conflicts between vehicles and pedestrians were almost eliminated for the treated intersections. Another similar study by Van Houten and colleagues (1997) considered an auditory pedestrian signal to prompt those crossing to look for turning vehicles, once the turn signal was on. This was found to be effective, and reduced pedestrian-vehicle conflicts at the targeted intersections.

Lord, Smiley, and Haroun (1998) provide a human-factors analysis of issues at intersections, particularly for left-turning vehicles, for which a pedestrian is four times more likely to be struck compared to right-turning vehicles. First, drivers tend to scan right instead of left when making left turns, which means they are less likely to detect pedestrians on the left. Peripheral detection also becomes more difficult under demanding driving conditions. Older drivers (e.g., older than 60, although the cutoff age differs between studies) also have less effective depth perception and reduced field of view, leading them to be a greater risk to pedestrians during turning maneuvers. Furthermore, on the pedestrian side, almost half of pedestrians walk slower than the identified engineering standard of that time for crossing a street at 1.22 meters per second (4 ft/s), with the primary vulnerable subpopulation being elderly pedestrians. As a side note, the current engineering standard is 1.07 meters per second (3.5 ft/s; MUTCD, 2009; Chapter

4E). Also, assessment of so-called elderly or older adults is somewhat unreliable, given absence of a universally agreed upon cutoff for when an adult can be categorized as older or elderly. In any case, pedestrians may not understand traffic signals, and both children and older adults may have less efficient visual scanning and search strategies. Most pedestrians, in general, do not effectively visually search for drivers turning left (Lord, Smiley, & Haroun, 1998).

Van Houten and colleagues (1999) considered alternative signals to improve the likelihood that pedestrians would check for left-turning vehicles, particularly an animated eyes display (a moving image of eyes on a display that is “looking” at the roadway) to signal the appropriate behavior at the intersection, which may be easy to understand and easily draws attention. The study found that the intervention had an effect which was sustained over six months. Another study considered a 3-second leading pedestrian interval (LPI) and found that introducing LPIs with that duration reduced conflicts between vehicles and pedestrians at targeted intersections and reduced the likelihood that pedestrians surrendered their right-of-way to vehicles (Van Houten, Retting, Farmer, & Van Houten, 2000).

Retting and Van Houten (2000) found that painted stop lines moved 20 feet from the crosswalk (as opposed to the standard 4 feet, see MUTCD, 2009; Chapter 3B) not only had good compliance with the advance stop lines, but that significantly more drivers stopped at least four feet back from the crosswalks. Furthermore, Retting and colleagues (2002) found that traffic signs prohibiting right turn on red (RTOR) increased driver compliance with stop lines, and reduced the frequency of drivers turning right on red without stopping and reduced the likelihood that pedestrians yielded the right of way to turning vehicles. However, signs giving driver's discretion to turn based on the presence of pedestrians were not effective, suggesting a blanket prohibition is more useful in this context.

Intersections are particularly risky to visually impaired pedestrians. Bentzen, Barlow, and Bond (2004) had sixteen visually impaired participants cross at unfamiliar signalized intersections without pedestrian signals. The study confirmed that this population of pedestrians have difficulty finding crosswalks, aligning themselves on a straight crossing route, and finishing crossings before traffic approaches. Thus, any interventions should carefully consider how they will affect visually impaired pedestrians.

Tiwari and colleagues (2007) performed a study of pedestrian crossing decisions in Delhi, India, and considered factors that influence these decisions by video review and coding. Men tended to wait less than women. As waiting time increased at a traffic signal, pedestrians were more likely to cross against the signal, which is unsafe. Brosseau and colleagues (2013) considered a similar question at signalized intersections in Montreal, Canada. Pedestrian violations of the crossing signal were more likely to occur with greater maximum waiting time, less pedestrian flow and smaller group size, older individuals, men, and the lack of a countdown timer. Furthermore, Kitali and colleagues (2018) found that pedestrian countdown signals (PCS) have a positive effect on both pedestrian and driver safety, the latter by causing a reduction in rear-end crashes as drivers are also monitoring the PCS and thus have more accurate expectations. Li (2013) conducted a similar study on pedestrian waiting times and found that there is a U-shaped distribution of pedestrian waiting times, with a proportion of pedestrians immediately crossing once they arrive at the crosswalk, and another proportion that waits the entire waiting phase.

Miranda-Moreno and colleagues (2011) looked at crash data requiring ambulance services to determine the contribution of the built environment (land use types, road network, demographics, etc.) on pedestrian crashes and activity. The primary finding was that the impact of the built environment had an indirect effect on pedestrian crashes by affecting pedestrian activity. With no safety approaches, increased density of the road network and increased transit may increase pedestrian activity and then increase pedestrian crashes. Motor vehicle volume is also a major contributor to pedestrian crashes. Major arterials are an exception, as they increase traffic volume but decrease pedestrian activity. However, Pulugurtha and Sambhara (2011) note that pedestrian activity is not necessarily directly linked to pedestrian crashes at signalized intersections, when analyzing crash data for 176 intersections in Charlotte, North Carolina. By relying less on traffic data and more on demographic, land use, road, and socio-economic data, they were able to better fit their model to crash rates. Specifically, land use variables (single family residential area, urban residential commercial area, commercial center,etc.) were negatively associated with pedestrian crashes and positively associated with pedestrian activity. The authors argued this was because drivers were more attentive and aware of the possibility of pedestrians in the area. Besides land use, number of intersection approaches and number of transit stops per unit of measurement (e.g., within .5 miles, or 1 mile) were positively associated with crashes. Finally, the authors argued that different predictive models needed to be made for intersections with low and high pedestrian activity (Pulugurtha & Sambhara, 2011).

Flashing yellow arrows have been introduced in some locations to replace protected left turns in order to increase traffic flow. Hurwitz and Monsere (2013) investigated whether these signals have an adverse effect on pedestrian safety. Using a driving simulator with eye-tracking to consider permissive left-turn scenarios, the researchers found that as the number of approaching vehicles increased, the less drivers would fixate on pedestrians on the crosswalk, suggesting that permissive turns as allowed by flashing yellow arrows should not be allowed when pedestrians are present, at least in the context where the alternative is providing a protected left turn, which may not be feasible in some circumstances.

Onelcin and Alver (2015) considered factors impacting safety margins and other crossing variables for pedestrians making illegal crossings at signalized intersections in Turkey. They found that illegal crossing decisions were primarily made based on the vehicle position (e.g., distance) and not necessarily the time to contact or vehicle speed. Crossing times were longer when approaching vehicles were at greater distances.

Crossing behaviors of pedestrians at crosswalks is different from pedestrians walking in ordinary spaces, and is influenced by signals, potential motor-vehicle conflicts, and the geometry of the intersection (Iryo-Asano & Alhajyaseen, 2017). One unique behavior is sudden speed changes in which the pedestrian quickly speeds up their walking pace, as opposed to modeling a constant walking speed. One study found that these sudden speed changes could be predicted as a discrete choice model, and the decision to engage in speed change is informed by the needed speed to complete crossing before the end of the crossing interval and the current speed, along with the presence of turning vehicles (Iryo-Asano & Alhajyaseen, 2017).

Another study used a survey in India to examine what contributed to the likelihood of a violation of crossing laws (e.g., walk signals) (Mukherjee & Mitra, 2019). The factors contributing to the likelihood of violations included average waiting time before crossing, pedestrians being distracted, pedestrians seeking public transport (e.g., chasing the bus), younger pedestrians (16-49 years), and whether the pedestrian's home was nearby. The pedestrian was less likely to violate the traffic signal if they were at a location with higher traffic volume or if they were going to work.

Jiang and colleagues (2020) found that pedestrians are less safe in channelized right-turn lanes at signalized intersections in China. They found non-channelized right-turn lanes to be the safest of the three options due to the lower speeds. Jiang and colleagues (2020) also note that some drivers are unable to slow down sufficiently to yield the right of way due to the higher approach speeds when the turning radius increases at channelized right-turn lanes. However, it may be feasible to design a channelized right-turn lane that reduces the sides of the corner radius and mitigates the speed factor. Stipancic, Miranda-Moreno, Strauss, and Labbe (2020) conducted a large-scale analysis across 1,864 intersections in Montreal, to further assess traffic and built environment factors on pedestrian safety, specifically at signalized intersections. They also found positive effects of the built environment, specifically that curb extensions, exclusive left-turn lanes, and raised medians all reduced pedestrian injuries, while the number of commercial entrances and number of lanes increased the likelihood of pedestrian injuries. There was a positive relationship between pedestrian and vehicle volumes and pedestrian injuries. Finally, pedestrian priority phases decreased the pedestrian injuries while straight green arrows increased injuries.

CHAPTER 2: METHODS

2.1 INITIAL STUDY DESIGN

The study aimed to determine the strength of individual treatment components of a high-visibility pedestrian safety program deployed in both the cities of Saint Paul and Minneapolis. The proposed treatments were selected to leverage ongoing enforcement activities relating to the Minnesota crosswalk law by the Saint Paul Police Department and examine the strength of enforcement in isolation and in combination with engineering. In Saint Paul, the research proposed a 3x2 design in which three treatment types (No treatment, Enforcement + Engineering, and Enforcement Only) would be applied to two Intersection types (Unsignalized and Signalized). Three intersection type pairings were selected for each of the three treatment groups (nine pairings for a total of 18 sites).

The initial treatments selected for the city of Minneapolis aimed to leverage the absence of ongoing enforcement activities relating to the crosswalk law by their police department to enable a more controlled examination of engineering efforts in isolation. In Minneapolis, the research proposed a 2x2 design in which two treatment types (No Treatment and Engineering Only) would be applied to two Intersection types (Unsignalized and Signalized). Four intersection type pairings were selected for each of the two treatment groups (8 pairings for a total of 16 sites).

2.1.1 Initial Site Selection

The research team worked with city, county, and state partners to review existing pedestrian crash analyses in each city. Pedestrian safety plans relating to Saint Paul (CH2M, 2016) and Ramsey County (CH2M/SRF, 2013) were examined along with the City of Saint Paul's Crash Map – Open Data Portal to identify candidate intersections to include in the study. Similarly, safety plans relating to Minneapolis were examined along with crash data provided by the Minnesota Department of Transportation including crashes in Minneapolis over the past 5 years.

The key strategy for selecting intersections was to prioritize those that have a history of multiple or serious injury pedestrian crashes on highly traveled roadways. Half of the study sites selected were signalized intersections and each was selected with consideration based on the availability of an adjacent unsignalized, marked intersection with similar pedestrian crash risks. Additional considerations were distribution or geographic spread of the study sites, feasibility for treatment (e.g., engineering or enforcement), and previous inclusion in research activities. The initial sites were reviewed with city and county partners and were revised based on geographic spread, feasibility of engineering treatment (or lack of treatment), generalization of roadway features or geometry, and potential to mark the crosswalk. The initial and revised sites are discussed below.

2.1.1.1 Proposed Saint Paul Sites

In total, nine pairs of intersections were initially selected in Saint Paul. Some pairings included notation of possible issues with their study inclusion or the lack of available adjacent pairing in its vicinity. These sites are listed in Table 2.1 and Figure 2.1. These sites were not selected with a treatment type in mind and would need to be assigned to one of three treatment conditions: Generalization (no treatment), Enforcement Treatment, or Enforcement + Engineering Treatment.

Table 2.1 Initial sites identified for Saint Paul

Pair	Signalized	Unsignalized
1	Snelling & Selby	Snelling & Laurel
2	W 7th & St Clair	W 7th & Michigan
3	S Robert & Cesar Chavez	S Robert & Isabel
4	Maryland & Rice	Maryland & Woodbridge
5	Maryland & Arcade	Maryland & Greenbrier
6	Ford Pkwy & S Finn	Ford Pkwy & Mount Curve (*Bike crash*)
		W Pinehurst & Cleveland (*Not in sight line*)
7	University & Dale (*may be too complex*)	University & Arundel
8	E 7th & Arcade	E 7th & Bates (*previously used*)
9	White Bear & Old Hudson Rd	White Bear & Wilson (*unmarked*)
Other considered sites		
10	Larpenteur Ave & Rice St.	Larpenteur & Galtier

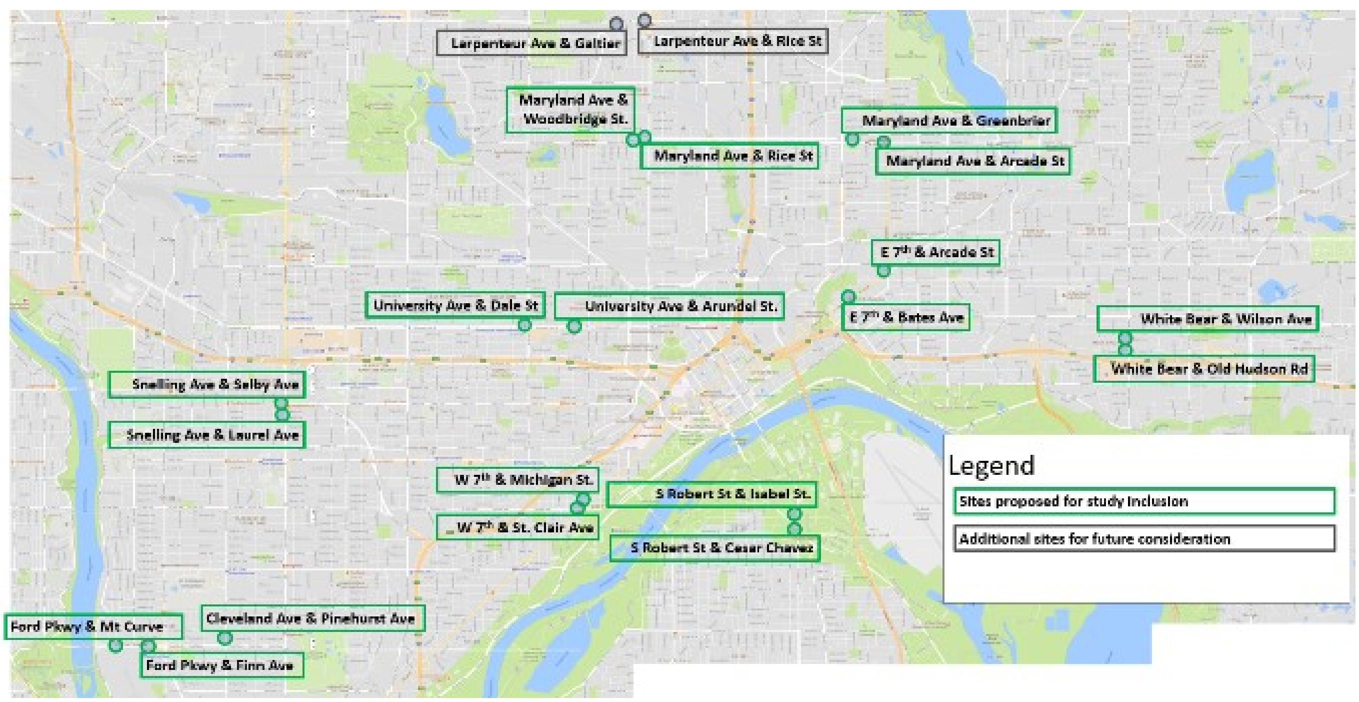


Figure 2.1 Possible study sites demonstrated on the Saint Paul map to denote pairings.

After review and discussion with City of Saint Paul and Ramsey County partners, sites that were identified as poor candidates for inclusion in the study were removed from consideration. The issues ranged from unique roadway designs with poor generalization to other sites (i.e., Cesar Chavez & Roberts) to inability to mark the unsignalized crosswalk (i.e., White Bear & Wilson). The remaining initial sites that were not noted to have limitations to receive engineering treatment were labeled as possible assignments to the Enforcement + Engineering group. The remaining sites were labeled as possible assignments to the Enforcement Only group or Generalization group. Additional sites were proposed to replace the removed site pairings. The revised study sites for Saint Paul are listed in Table 2.2 and shown in Figure 2.2.

Table 2.2 Revised sites identified for Saint Paul

Pair	Signalized	Unsignalized	Treatment Type
1	Snelling & Selby	Snelling & Laurel	Enforcement Only
2	W 7th & St Clair	W 7th & Michigan	Enforcement Only
3	E 7th & Arcade	E 7th & Bates (*previously used*)	Enforcement Only
4	Ford Pkwy & S Finn	Ford Pkwy & Mount Curve (*Bike crash*)	Enforcement + Engineering
5	Maryland & Arcade	Arcade & Jessamine (*previously used*)	Enforcement + Engineering
6	Larpenteur & Rice	Larpenteur & Galtier	Enforcement + Engineering
7	University & Dale	University & Arundel	Generalization Site
8	Maryland Ave & Rice St	Maryland Ave & Woodbridge St	Generalization Site
9	White Bear & Maryland Ave	White Bear & Hazel Park Prep	Generalization Site

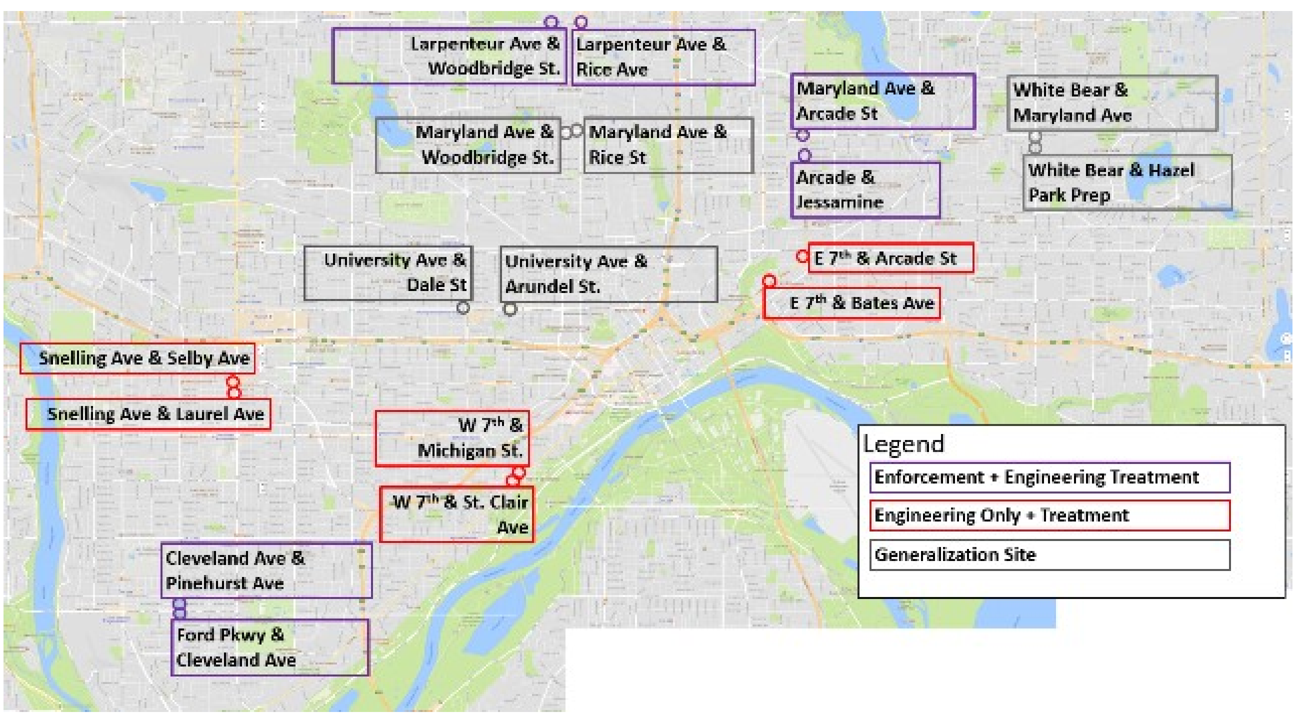


Figure 2.2 Revised study sites demonstrated on the Saint Paul map to denote pairings.

2.1.1.2 Proposed Minneapolis Sites

In total, eight pairs of intersections were initially selected in Minneapolis. Some pairings include notation of possible issues with their study inclusion or the lack of available adjacent pairing in its vicinity. These sites are listed in Table 2.3 and Figure 2.3. These sites were selected for assignment to one of two treatment conditions: Generalization (no treatment) and Engineering Treatment. Based on guidance from the City of Minneapolis staff, pairings one to four were selected for engineering treatment assignment to coincide with other planned improvements by the city.

Table 2.3 Initial sites identified for Minneapolis

Pair	Signalized	Unsignalized
1	Hennepin Ave & N 16th St.	16th St N & Laurel Ave W
2	Chicago Ave & S 8th St.	S 9th Ave & S 8th St.
3	35th St & Nicollet Ave	35th St & Pleasant Ave
4	E 28th St & Nicollet Ave	29th St & Pillsbury Ave (not in sight line, not marked)
5	W Franklin Ave & Nicollet Ave	E 19th St & Nicollet Ave
6	W 28th St & Hennepin Ave	W 28th St & Humboldt Ave
Other sites to consider		
7	38th St & Nicollet Ave	39th St & Nicollet Ave

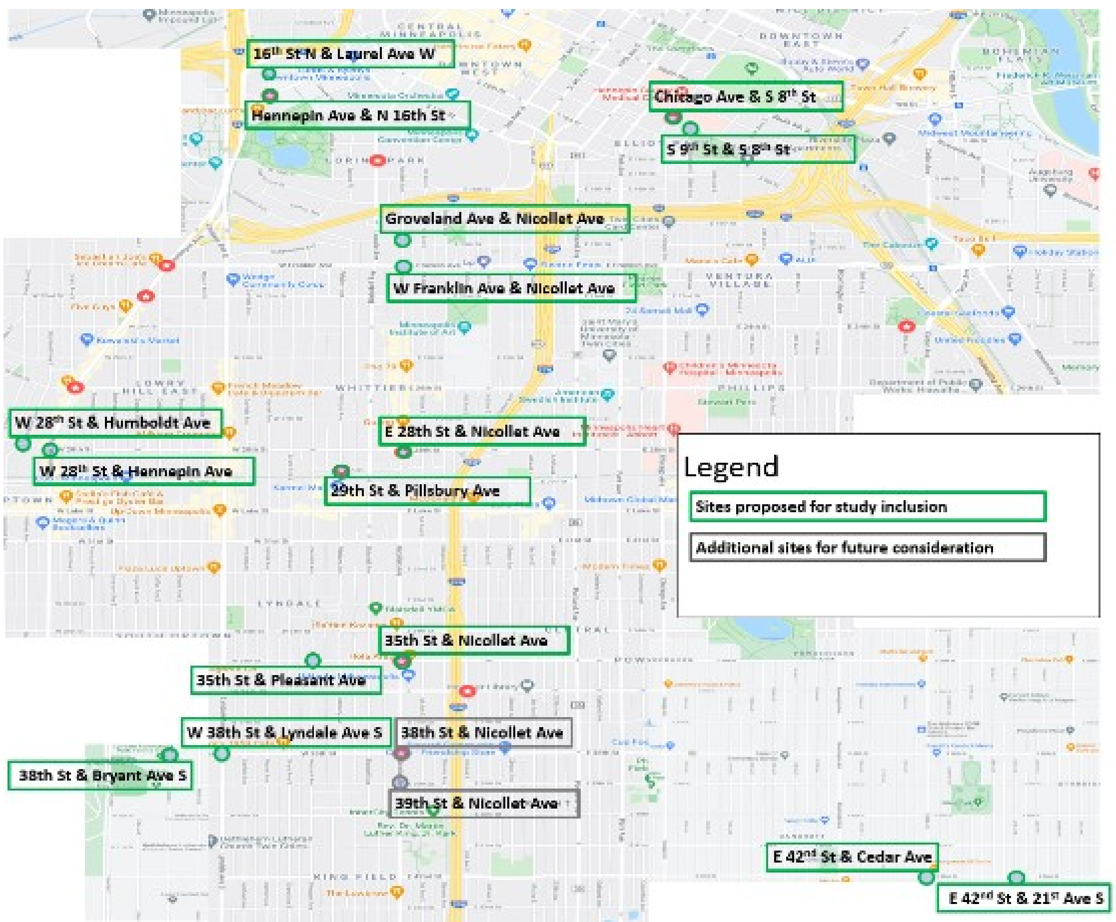


Figure 2.3 Possible study sites demonstrated on the Minneapolis map to denote pairings.

After review and discussion with the City of Minneapolis, sites that were identified as poor candidates for inclusion in the study were removed from consideration. The main reasons for removal were to allow greater dispersion to include a larger geographic distribution of sites, with particular emphasis to include locations in north Minneapolis. Additionally, the site pairings were originally selected to capitalize on the few marked, unsignalized crosswalks near locations identified as priority for treatment. An alternative approach was suggested by the city to select sites that currently have no marking. Generalization sites would be marked prior to data collection for the study and treatment sites would be marked as a component of the engineering treatment. The revised study sites for Minneapolis are listed in Table 2.4 and shown in Figure 2.4. Satellite images of intersections from each of the eight pairings are included in Appendix B.

Table 2.4 Revised sites identified for Minneapolis

Pair	Signalized	Unsignalized	Treatment Type
1	Fremont Ave N & Dowling Ave N	Dowling Ave N. & N Bryant Ave	Engineering only
2	Lyndale Ave N & 18th Ave N	Lyndale Ave N & N 21st Ave	Engineering only
3	Chicago Ave & S 8th St	Chicago Ave & E 15th St	Engineering only
4	35th St & Nicollet Ave	37th St & Nicollet Ave	Engineering only
5	Lyndale Ave N & Lowry Ave	Lyndale Ave & N 33rd Ave	Generalization Site
6	N 2nd St & Lowry Ave	N 2nd St & N 30th Ave	Generalization Site
7	W Franklin Ave & Nicollet Ave	W 22nd St & Nicollet Ave	Generalization Site
8	38th St & Nicollet Ave	39th St & Nicollet Ave	Generalization Site

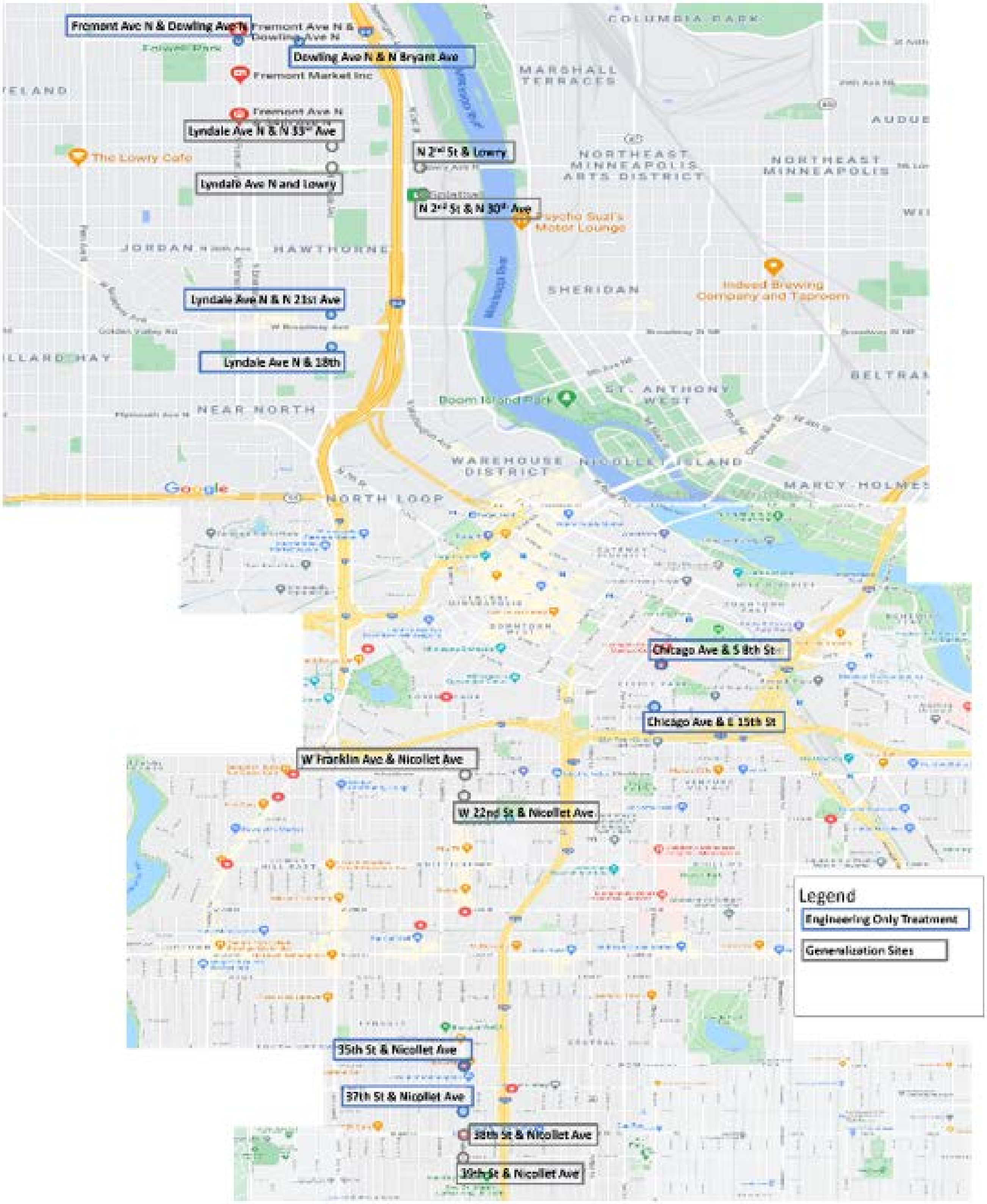


Figure 2.4 Revised study sites demonstrated on the Minneapolis map to denote pairings.

2.2 FINAL STUDY DESIGN

The initial study designs were changed in the months prior to data collection for this study due to concerns from Minnesota Department of Transportation leadership regarding regional socio-political climate regarding police enforcement and public safety. At the time of the decision, there was uncertainty if Saint Paul police would be available to carry out the planned Stop For Me operations since the final verdict of police officer Derrick Chauvin being tried for the murder of George Floyd had not yet been announced. Additionally, there was concerns raised by some district councils in Saint Paul regarding their level of support for the program if it included police enforcement as a component of treatment. As a result of these concerns, the high-visibility enforcement (HVE) component of the study was removed from the study treatment plan.

This shift in methodological design removed the Enforcement + Engineering and Engineering Only treatment types from the treatment plan in Saint Paul and reduced both cities to a modified 2x2 design in which two treatment types (No Treatment and Engineering Only) will be applied to two intersection types (Unsignalized and Signalized).

2.2.1 Final Site Selection

2.2.1.1 Final Saint Paul Sites

Following the final methodological design changes, several changes were made to the final site selection to accommodate the 2X2 design in Saint Paul. Additionally, initial data probing at selected sites, along with other issues, resulted in a change to study sites. The resultant sites and the reason for their change are listed below.

White Bear & Sherwood. The original site (White Bear & Hazel Park Prep) was deemed to be significantly risky for staged crossings given high speeds of drivers along this section of White Bear Ave. The combined high speeds, along with observed poor driver expectancies that pedestrians would cross at this marked crosswalk near Hazel Park Prep school, was predicted to have a high risk of rear-end collisions for drivers who are stopping for pedestrians. For safety concerns, the research team moved the measurement site to White Bear & Sherwood.

Larpenteur & Woodbridge. The original site (Larpenteur & Galtier) was found to be signed at 45 mph, which was deemed too fast for safe crossings by the research team. The nearby site at Woodbridge (i.e., signed at 35 mph with a pedestrian refuge) was selected instead.

Ford & Cleveland. The original site (Ford Pkwy & S Finn St) was slated for major construction during the data collection period. Following consultation with the Highland Park district council, the research team moved the measurement site to the nearby signalized intersection of Ford Pkwy & Cleveland Ave S.

Cleveland & Pinehurst. The original site (Ford Pkwy & Mount Curve) was slated for major construction during the data collection period. Following consultation with the Highland Park district council, the research team moved the measurement site to the nearby unsignalized intersection of Cleveland Ave S & W Pinehurst Ave.

The revised study sites for Saint Paul are listed in Table 2.5. Further details regarding the eight final site pairings are included in Table 2.6 and Table 2.7 which provide average daily traffic (ADT) and number of lanes. Satellite images of intersections from each of the eight pairings are included in Appendix A.

Table 2.5 Final sites identified for Saint Paul

Pair	Signalized	Unsignalized	Treatment Type
1	Snelling & Selby	Snelling & Laurel	Engineering Site
2	W 7th & St Clair	W 7th & Michigan	Generalization Site
3	Ford Pkwy & Cleveland Ave	Cleveland Ave & Pinehurst Ave	Engineering Site
4	Maryland & Arcade	Arcade & Jessamine (*previously used*)	Engineering Site
5	Larpenteur & Rice	Larpenteur & Woodbridge	Engineering Site
6	University & Dale	University & Arundel	Generalization Site
7	Maryland Ave & Rice St	Maryland Ave & Woodbridge St	Generalization Site
8	White Bear & Maryland Ave	White Bear & Sherwood Ave	Generalization Site

Table 2.6 Revised sites identified for Saint Paul listed with available ADT data for each roadway

Pair	Signalized				Unsignalized			
1	Snelling	37000 (2018); 26000 (2012)	Selby	4750 (2019); 14800 (2018)	Snelling	26000 (2012)	Laurel	-
2	W 7th	10800 (2019)	St Clair	7300 (2017); 4900 (2019)	W 7th	10800 (2019)	Michigan	-
3	Ford Pkwy	18900 (2018); 12200 (2017)	Cleveland Ave	12100 (2018); 15100 (2018)	Cleveland Ave	12100 (2018)	Pinehurst Ave	-
4	Maryland	18600 (2016); 19400 (2018)	Arcade	13000 (2018); 11800 (2018)	Arcade	13000 (2018)	Jessamine	-
5	Larpenteur	13300 (2018)	Rice	15100 (2018); 13500 (2019)	Larpenteur	13300 (2018)	Woodbridge St	-
6	University	15100 (2016); 14100 (2016)	Dale	21900 (2018); 18100 (2018)	University	14100 (2016)	Arundel	-
7	Maryland Ave	12700 (2019); 15100 (2011)	Rice	15400 (2015); 14000 (2017)	Maryland Ave	12700 (2019)	Woodbridge St	-
8	White Bear	19400 (2011); 18800 (2011)	Maryland Ave	11100 (2018); 3300 (2018)	White Bear	19400 (2011)	Sherwood Ave	-

Note. Two numbers indicate estimated ADT of opposite sides of intersection, if available. Dashes (-) mean no estimate available. Numbers in parentheses ( ) indicate the year of report. Retrieved from: http://www.dot.state.mn.us/traffic/data/tma.html

Table 2.7 Lane count of revised sites identified for Saint Paul

Pair	Signalized				Unsignalized			
1	Snelling	4L+1T	Selby	2L + 1T	Snelling	4L + 1T	Laurel	2L
2	W 7th	2L+1T	St Clair	2L	W 7th	2L + 1T	Michigan	2L
3	Ford Pkwy	4L+1T	Cleveland	2L + 1T	Cleveland	2L + 1T	Pinehurst	2L
4	Maryland	2L+2T	Arcade	4L	Arcade	4L	Jessamine	2L
5	Larpenteur	4L+1T	Rice	2L + 2T	Larpenteur	4L	Woodbridge	2L
6	University	4L+1T+Rail	Dale	4L + 1T / 2T	University	4L + Rail	Arundel	2L
7	Maryland	4L+1T	Rice	4L	Maryland	2L	Woodbridge	2L
8	White Bear	4L+1T	Maryland	2L + 1T	White Bear	4L	Sherwood	2L

Note. L = Lanes, T = Turn Lane Only, / means different types or counts for each side of the intersection.

2.2.1.2 Final Minneapolis Sites

In addition to changes needed following the revised study design, several changes were made to the final site selection in Minneapolis due to construction. The resultant sites and the reason for their change are listed below.

Chicago Ave & 16th. The original site (Chicago and 15th) was under construction, so the research team measured yielding at a nearby signalized site (Chicago and 16th) as a proxy measure.

Lyndale Ave N & Dowling Ave N. The original signalized site (Dowling Ave N and Freemont Ave N) was under construction, so the research team measured yielding and looking behavior at the nearby signalized intersection of Lyndale Ave N & Dowling Ave N. This site was proposed to receive engineering treatment; however, due to a lack of treatment installation at this site the data collected at this site has been treated and analyzed as a generalization site.

The revised study sites for Minneapolis are listed in Table 2.8. Further details regarding the final eight site pairings are included in Table 2.9 and Table 2.10 which provide average daily traffic (ADT) and number of lanes. Satellite images of intersections from each of the eight pairings are included in Appendix B.

Table 2.8 Final sites identified for Minneapolis

Pair	Signalized	Unsignalized	Treatment Type
1	Lyndale Ave N & Dowling Ave N	Dowling Ave N. & N Bryant Ave	Generalization Site
2	Lyndale Ave N & 18th Ave N	Lyndale Ave N & N 21st Ave	Engineering Site
3	Chicago Ave & S 8th St	Chicago Ave & E 16th St	Engineering Site
4	35th St & Nicollet Ave	37th St & Nicollet Ave	Engineering Site
5	Lyndale Ave N & Lowry Ave	Lyndale Ave & N 33rd Ave	Generalization Site
6	N 2nd St & Lowry Ave	N 2nd St & N 30th Ave	Generalization Site
7	W Franklin Ave & Nicollet Ave	W 22nd St & Nicollet Ave	Generalization Site
8	38th St & Nicollet Ave	39th St & Nicollet Ave	Generalization Site

Table 2.9 Final sites identified for Minneapolis listed with available ADT data for each roadway

Pair	Signalized				Unsignalized			
1	Lyndale Ave N	8000 (2017); 9000 (2017)	Dowling Ave N	10300 (2017); 16700 (2017)	Dowling Ave N	10300 (2017)	N Bryant Ave	-
2	Lyndale Ave N	7800 (2017)	18th Ave N	-	Lyndale Ave N	9000 (2017)	N 21st Ave	-
3	Chicago Ave	7000 (2018)	S 8th St	6300 (2018)	Chicago Ave	UNK	E 16th St	-
4	35th St	10000 (2015); 4800 (2019)	Nicollet Ave	8700 (2019); 9200 (2019)	37th St	8700 (2019)	Nicollet Ave	-
5	Lyndale Ave N	9000 (2017); 8000 (2017)	Lowry Ave	15200 (2017); 13700 (2017)	Lyndale Ave	8000 (2017)	N 33rd Ave	-
6	N 2nd St	6800 (2017); 8000 (2017)	Lowry Ave	13700 (2017); 15000 (2017)	N 2nd St	8000 (2017)	N 30th Ave	-
7	W Franklin Ave	15000 (2019); 23600 (2019)	Nicollet Ave	6400 (2019)	W 22nd St	6400 (2019)	Nicollet Ave	-
8	38th St	4700 (2019); 9800 (2016)	Nicollet Ave	10700 (2019); 8700 (2019)	39th St	10700 (2019)	Nicollet Ave	-

Note. Two numbers indicate estimated ADT of opposite sides of intersection, if available. Dashes (-) mean no estimate available. Numbers in parentheses ( ) indicate the year of report. Retrieved from: http://www.dot.state.mn.us/traffic/data/tma.html

Table 2.10 Lane count of final sites identified for Minneapolis

Pair	Signalized				Unsignalized			
1	Lyndale Ave N	2L	Dowling Ave N	2L+1T+BL	Dowling Ave N	2L/BL	N Bryant Ave	2L
2	Lyndale Ave N	4L	18th Ave N	2L	Lyndale Ave N	4L	N 21st Ave	2L
3	Chicago Ave	2L	S 8th St.	3L (1-way)	Chicago Ave	2L	E 16th St	2L (1-way)
4	35th St	2L (1-way)	Nicollet Ave	2L	37th St	2L	Nicollet Ave	2L
5	Lyndale Ave N	2L	Lowry Ave	4L+BL+1T	Lyndale Ave	2L	N 33rd Ave	2L
6	N 2nd St	2L+BL	Lowry Ave	4L	N 2nd St	2L+BL	N 30th Ave	2L
7	W Franklin Ave	4L	Nicollet Ave	2L+1T	W 22nd St	2L	Nicollet Ave	2L+1T
8	38th St	2L	Nicollet Ave	2L	39th St	2L	Nicollet Ave	2L

Note. L = Lanes, T = Turn Lane Only, BL = Bike Lane, / means different types or counts for each side of the intersection.

Notably, fewer locations selected in Saint Paul featured two lane roadways compared to Minneapolis locations. Of the unsignalized locations, only three of the eight locations featured a two-lane road on the thru road, two of those with an additional turn lane, while seven of the eight Minneapolis main roads were two-lane. Of the signalized locations, six of the eight Saint Paul locations had a two-lane road, but only one of those were two-lane for both intersecting roads. In contrast, all eight of the Minneapolis signalized intersections had a two-lane road for one of the intersecting roads and two of those were two-lane for both intersecting roads. This imbalance of a greater number of four-lane roadways included in Saint Paul would be expected to result in more challenging and risky driving conditions for pedestrians to cross as compared to Minneapolis, absent other factors influencing driving behavior.

2.3 IMPLEMENTATION PLAN DEVELOPMENT

2.3.1 Treatment and Engineering Plan

Due to shifting timelines and available resources as a result of the shift in methodological design, the implemented treatment and engineering differed from the initial implementation plan in regard to both time frames and installed treatment by site. The final report outlines both the initially proposed treatment and engineering plan as well as the final implemented treatments of the study.

The signalized intersection implementation plans in Minneapolis (see Table 2.11) and in Saint Paul (see

Table 2.12) proposed a mix of leading pedestrian intervals (LPIs), bollard treatments, stop bars, and signage to alert turning drivers to stop for pedestrians (see Figure 2.5, left). Further, the initial plans include a suggested use of pedestrian signage aimed to encourage looking behavior for turning vehicles (see Figure 2.5, right). This suggested treatment is a complement to a similar signage treatment at unsignalized intersections aimed to promote pedestrian gesturing behavior to highlight the intent to cross, based on research by Crowley-Koch, Van Houten, and Lim (2011) (see Figure 2.6, right).

Figure 2.5 Proposed signalized intersection signage treatments for driver of turning vehicles (left) and pedestrians to watch for turning vehicles (right)

Table 2.11 Minneapolis Signalized Intersection Implementation Plan

	Fremont Ave N & Dowling Ave N	**Lyndale Ave N & 18th Ave N**	**Chicago Ave & S 8th St**	**35th St & Nicollet Ave**
Spring Prep				
1: Jun	Install LPI or striping change			
2: Jul	Install bollard centerline and any other bollard improvements shown on plans for each location			
3: Aug	Install “TURNING VEHICLES STOP FOR PEDESTRIANS” sign			
4: Sep	Install “WATCH FOR TURNING VEHICLES” sign			

Table 2.12 Saint Paul Signalized Intersection Implementation Plan

	Maryland Ave & Arcade St.	Larpenteur & Rice	Ford Pkwy & Cleveland Ave	Snelling Ave & Selby Ave.
Spring Prep	Refresh markings			
1: Jun	Install LPI or Stop Bars		Install Stop Bars	
2: Jul	Install hardened centerline (with or without bollards) Consider Slow turn wedge at SW corner	Install hardened centerline (with or without bollards)		
3: Aug	Install "TURNING VEHICLES STOP FOR PEDESTRIANS" sign			
4-Sep	Install "WATCH FOR TURNING VEHICLES" sign			

The unsignalized intersection implementation plans in Minneapolis (see Table 2.13) and in Saint Paul (see Table 2.14)) proposed a mix striping changes, standard pedestrian signage (see Figure 2.6, left), R1-6 in-street signage in single and gateway configurations (Figure 2.6, center), and bollard treatments (i.e., bollard bump outs and pedestrian medians).

Figure 2.6 Standard crosswalk sign (W11-2 with W16-7) (Left), R1-6 In-street pedestrian sign (Center), and Pedestrian signage to encourage gesturing (Right) (Crowley-Koch et al., 2011)

Table 2.13 Minneapolis Unsignalized Intersection Implementation Plan

	Lyndale Ave N & N 21st Ave	Dowling Ave N. & N Bryant Ave	Chicago Ave & E 15th St	37th St & Nicollet Ave
Spring Prep				
1: Jun	Install striping changes along Lyndale for 4-3 lane conversion with bike lanes	Mark a standard crosswalk on one leg across the busier street		
	Install a marked crosswalk on the southern leg across Lyndale	Install one standard crosswalk sign on nearest existing sign pole in each direction (2 total)		
	Mark a bright orange spray paint dot (golf ball to baseball size) in middle of each lane 10' and 40' away from the approach to the crosswalk. These dots are for use by the researchers.			
	Add one standard crosswalk sign on nearest existing sign pole in each direction (2 total)			
2: Jul	Install bollard pedestrian median	Install bollard bump outs or medians		
3: Aug	Add two R1-6 signs on the centerline on either side of each crosswalk			
4: Sep	Add advanced stop bars 10' in front of crosswalk. Add pedestrian sign guidance	Add additional gateway R1-6 signs and advanced stop bar. Add sign guidance for pedestrians.		

Table 2.14 Saint Paul Unsignalized Intersection Implementation Plan

<table>
<tr><th></th><th>Larpenteur & Woodbridge</th><th>Arcade & Jessamine</th><th>Snelling Ave & Laurel</th><th>Cleveland Ave & Pinehurst</th></tr>
<tr><td>Spring Prep</td><td></td><td></td><td></td><td></td></tr>
<tr><td>1: Jun</td><td colspan="3">Refresh marking</td><td>Refresh marking (consider moving to north side)</td></tr>
<tr><td>2: Jul</td><td></td><td>Add advanced stop bar or single R1-6 to south side of south crosswalk</td><td colspan="2">Add advanced stop bar or single R1-6 to north side of single marked crosswalk</td></tr>
<tr><td>3: Aug</td><td></td><td>Add single R1-6 to south side of south crosswalk or bollard bump out to crosswalk SW corner crosswalk to address transition from park lane to 2 lanes on other side</td><td colspan="2">Single R1-6 to north side of single marked crosswalk (bollard refuge on north side).</td></tr>
<tr><td>4: Sep</td><td>Add sign guidance for pedestrians.</td><td>Add additional R1-6 to northside or consider partial gateway (curb mounted) on both north and south side. Add sign guidance for pedestrians.</td><td colspan="2">Add additional R1-6 to southside or consider partial gateway (curb mounted) on both north and south side. Add sign guidance for pedestrians.</td></tr>
</table>

2.3.2 Community Feedback Signs

Minneapolis feedback signs to communicate driver stopping rates at unsignalized study sites will raise awareness of pedestrian safety, increase likelihood of media coverage, and increase safer behaviors. The signs were scheduled to be installed during the second wave in July. The research team has proposed that the locations for the signs in Saint Paul will be similar to the locations for the 2017-2019 study (Morris, Craig, & Van Houten, 2019), see Table 2.15. The one exception is the previous location on Snelling and LaFond, which was dangerous for the person responsible for updating the signs due to its height. An example of the feedback signs is provided in Figure 2.7 and Error! Reference source not found.. The mapped locations of the feedback signs, along with the final study sites, and shown in Figure 2.11 for Saint Paul and Figure 2.12 for Minneapolis.

Table 2.15 Proposed feedback sign locations.

Saint Paul Feedback Sign Locations
Snelling Ave, b/n Carroll Ave & Iglehart Ave
Lexington Pkwy N, b/n Concordia Ave & Marshall Ave
Maryland Ave E, b/n Edgerton St and Payne Ave
Maryland Ave E, b/n Clark and Arkwright St N
University Ave W, b/n Hampden Ave and Vandalia
Marshall Ave, b/n Mississippi River Blvd and Otis Ave
W 7th, b/n Springfield St. and S Homer St

Minneapolis Feedback Sign Locations
2 (1 in each direction) Hennepin/Lyndale @ Oak Grove St
2 (1 in each direction) on West Broadway near Washington Ave
Dowling EB just before I-94 interchange
Lake Street just west of Hennepin Ave
46th Street near I-35W interchange
University Ave SE just west of I-35W interchange

Figure 2.7 Saint Paul feedback sign design.

Figure 2.8 Minneapolis feedback sign design.

2.4 TREATMENT AND ENGINEERING IMPLEMENTATION

The participating agencies for implementation include Minnesota Department of Transportation, Minneapolis Vision Zero, Saint Paul Public Works, and Ramsey County. The implementation of the engineering treatment deviated from the plan in both treatment type and timeline. Unsignalized, unmarked crosswalks in Minneapolis were painted during the baseline period near the end of May. Treatments for both signalized and unsignalized intersections planned for June were delayed until July due to maintenance/construction delays. Treatments aimed at encouraging looking behavior for pedestrians at both intersection type (i.e., Figure 2.5 and Figure 2.6) were ultimately not installed. The final treatment wave was shifted to October and included R1-6 signs and temporary pedestrian refuge installation at Minneapolis unsignalized intersections, and hardened centerlines and advanced stop bars at signalized intersections in Saint Paul. Full details are described in the following sections.

2.4.1 Signalized Sites

The research team has provided a detailed summary of all treatments installed at signalized sites during the data collection period. It should be noted that not all exact dates of installation were shared with the research team, thus some installation dates are approximated based on when the research team first noted the presence of treatment at each site. See Figure 2.9 for a summary of treatment installed at each of the signalized sites and the corresponding week of data collection the treatment was installed. Also see Table 2.16 for each intervention engineering implemented with corresponding sites of implementation.

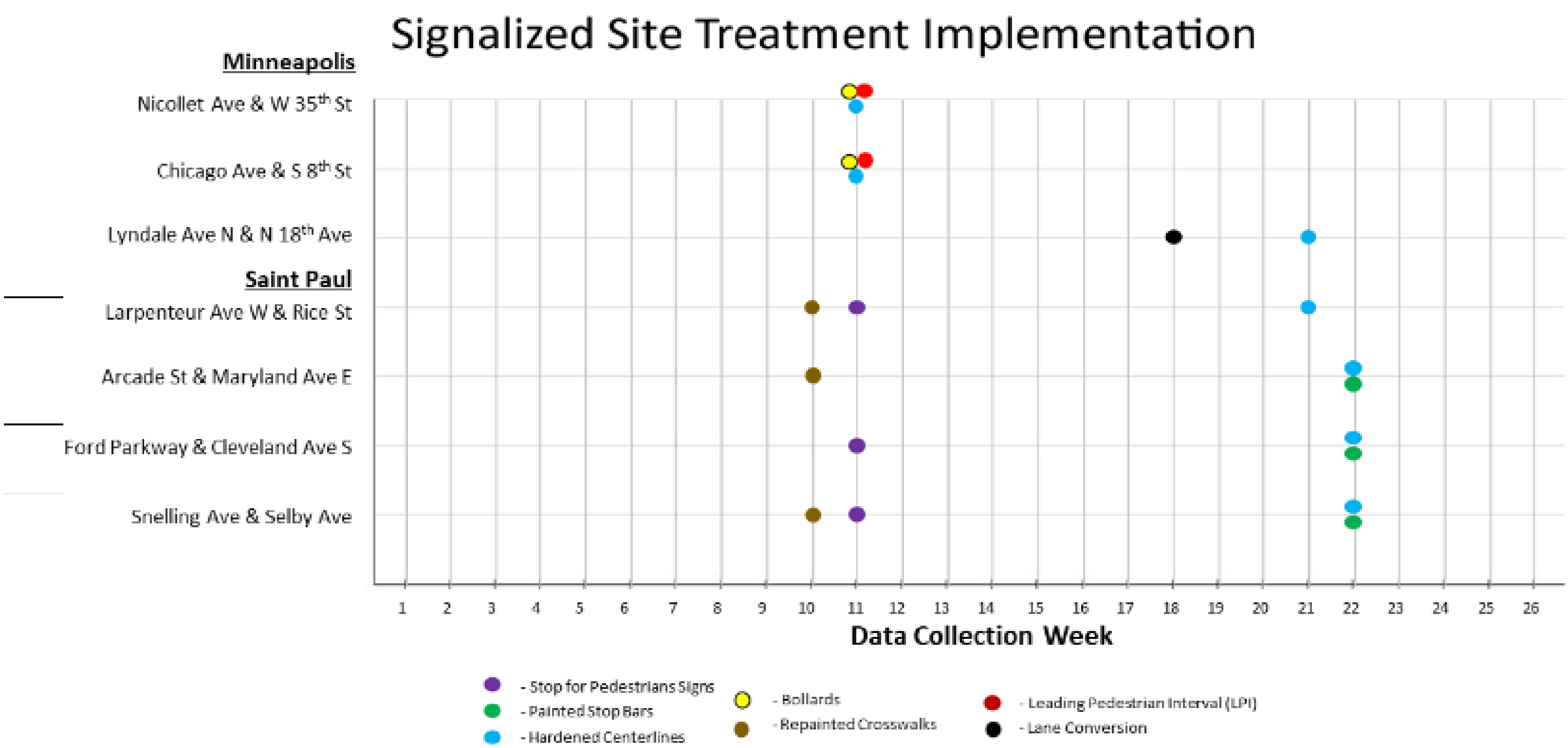
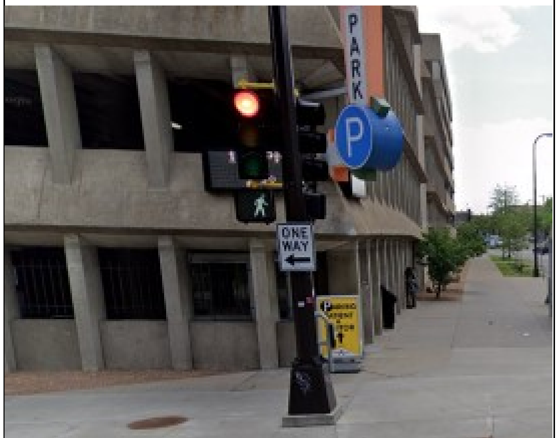


Figure 2.9 Treatment implementation timeline for signalized sites

Table 2.16 Signalized site treatments overview

Intervention Name	Figure	Sites Implemented
Stop for Pedestrian Sign		Snelling Ave & Selby Ave Ford Parkway & Cleveland Ave S Larpenteur Ave & Rice St
Stop Bars		Snelling Ave & Selby Ave Ford Parkway & Cleveland Ave S Arcade St & Maryland Ave E

Hardened Centerlines		Snelling Ave & Selby Ave Ford Parkway & Cleveland Ave S Arcade St & Maryland Ave E Larpenteur Ave & Rice St Lyndale Ave N & N 18th Ave Chicago Ave & S 8th St Nicollet Ave & W 35th St
Bollards		Chicago Ave & S 8th St Nicollet Ave & W 35th St
Repainted Crosswalks		Larpenteur Ave & Rice St Arcade St & Maryland Ave E Snelling Ave & Selby Ave

Leading Pedestrian Interval (LPI)		Chicago Ave & S 8th St Nicollet Ave & W 35th St
Lane Conversion		Lyndale Ave N & N 18th Ave

2.4.2 Unsignalized Sites

The research team has provided a detailed summary of all treatments installed at unsignalized sites during the data collection period. Again, it should be noted that not all exact dates of installation were shared with the research team, thus some installation dates are approximated based on when the research team first noted the presence of treatment at each site. See Figure 2.10 for a summary of treatment installed at each of the unsignalized sites and the corresponding week of data collection the treatment was installed. Also see Table 2.17 for each intervention engineering implemented with corresponding sites of implementation.

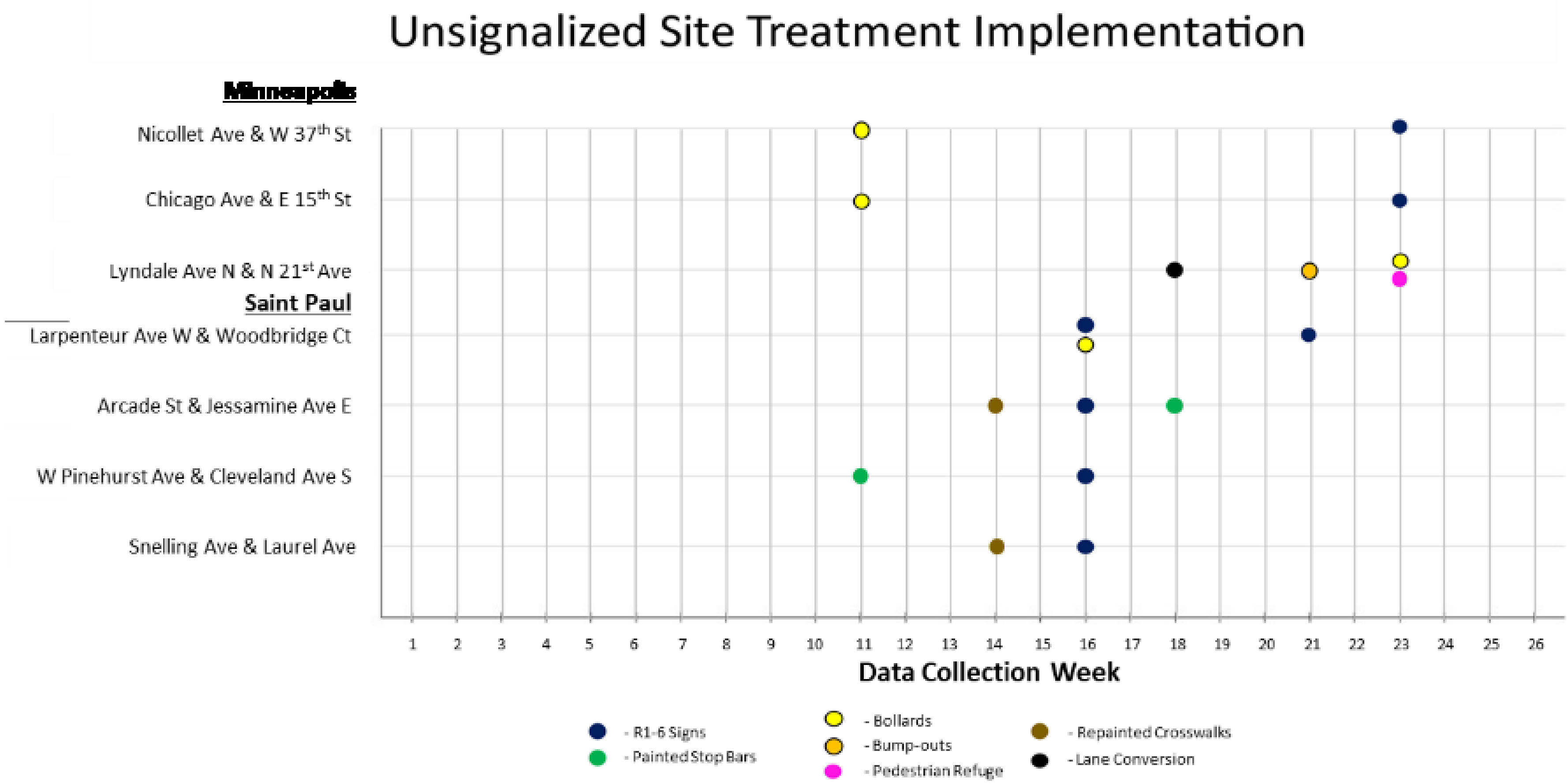


Figure 2.10 Treatment implementation timeline for unsignalized sites

Table 2.17 Unsignalized site treatments overview

Intervention Name	Figure	Sites Implemented
R1-6 Signs		Snelling Ave & Laurel Ave W Pinehurst Ave & Cleveland Ave S Arcade St & Jessamine Ave E Larpenteur Ave W & Woodbridge Ct Chicago Ave & E 15th St Nicollet Ave & W 37th St
Stop Bars		W Pinehurst Ave & Cleveland Ave S Arcade St & Jessamine Ave E
Bollards		Larpenteur Ave W & Woodbridge Ct Lyndale Ave N & N 21st Ave Chicago Ave & E 15th St Nicollet Ave & W 37th St

Bump-outs		Lyndale Ave N & N 21st Ave
Pedestrian Refuge		Lyndale Ave N & N 21st Ave
Repainted Crosswalks		Arcade St & Jessamine Ave E Snelling Ave & Laurel Ave
Lane Conversion		Lyndale Ave N & N 21st Ave

2.4.3 Community Feedback Signs

The community feedback signs were installed in mid-July (week 10) at locations similar to those initially proposed in the study and are listed in Table 2.18 and shown in the mapped locations in Figure 2.11 and Figure 2.12. Fewer signs were ultimately installed in Minneapolis than planned. Signs were populated with the previous week's weighted average yielding percent from observed conflicts at both unsignalized and signalized study sites. The citywide averages (i.e., treatment and generalization sites) or only treatment sites were used, which ever average was higher. Saint Paul signs were updated with retroreflective placards made by Saint Paul Public Works sign shop and installed by the research team. Saint Paul signs were mounted to permanent street furniture (e.g., light poles) or were mounted to posts fixed into the ground. Minneapolis signs were updated with non-reflective stickers made by Minneapolis Printing Office and installed by Minneapolis Public Works staff for the first two months and by the research team for the remaining months. Minneapolis signs were mounted to free standing posts and weighted with sandbags. Notably, Minneapolis signs were frequently knocked over (e.g., wind or loose sandbags) and were repositioned by the coding team during weekly updating, thus it is difficult to accurately measure the effectiveness of these signs and their true visibility to the public.

Table 2.18 Community feedback sign installed locations

Saint Paul Community Feedback Signs		University Ave & Hampden/Vandalia Ave Marshall Ave & Otis Ave Snelling Ave & Dayton Ave W 7th St & Homer Ave Lexington Ave & Concordia Ave Larpenteur Ave & Galtier St. Maryland Ave & Payne Ave Maryland Ave & Prosperity Ave
Minneapolis Community Feedback Signs		W Broadway Ave & N 4th St (East-Facing) W Broadway Ave & N 4th St (West-Facing) Hennepin Ave & 1st St S Lyndale Ave @ Oak Grove (South-facing) Lyndale Ave @ Oak Grove (North-facing) Lake St & Hennepin Ave

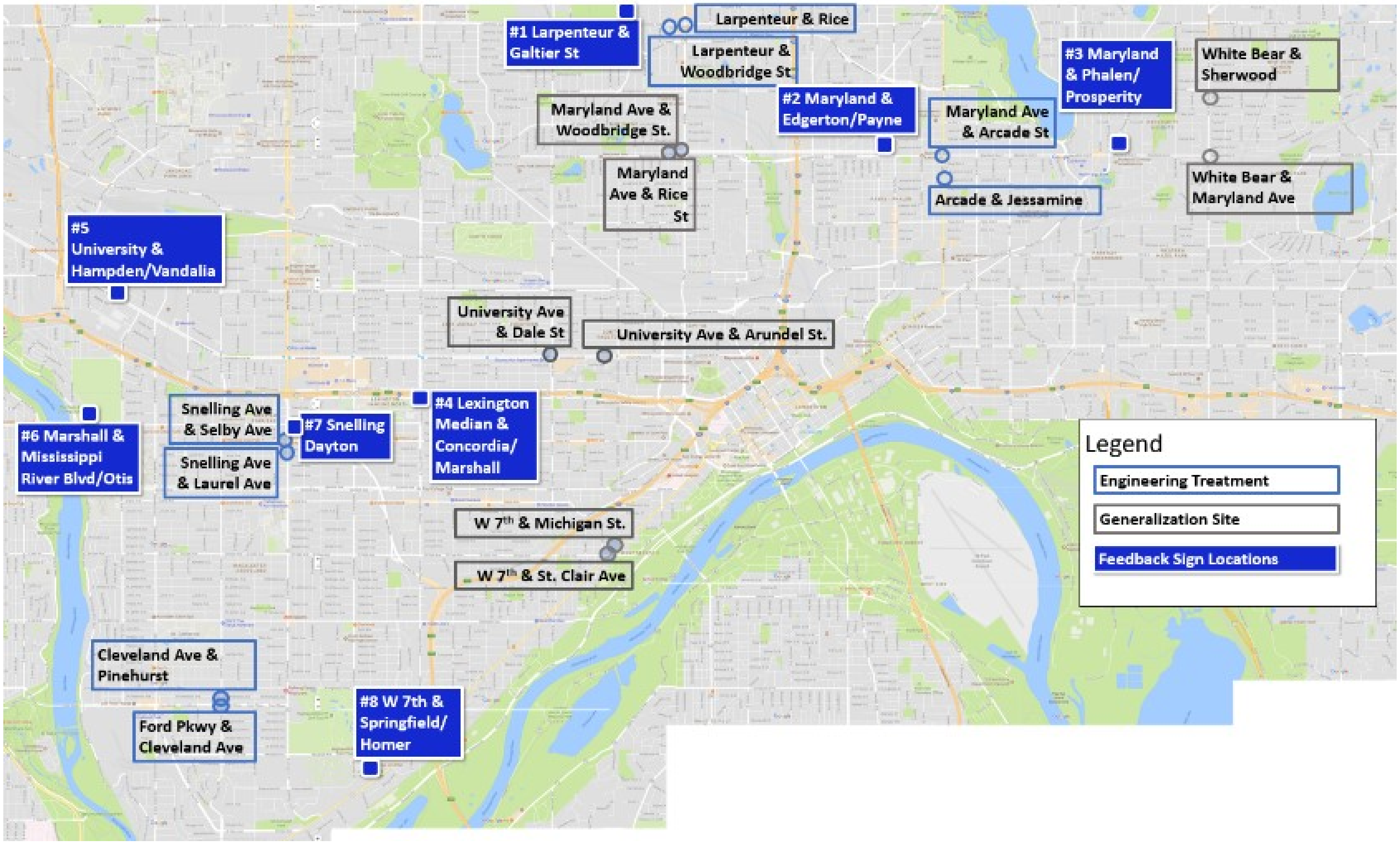


Figure 2.11 Saint Paul feedback sign locations and final study sites

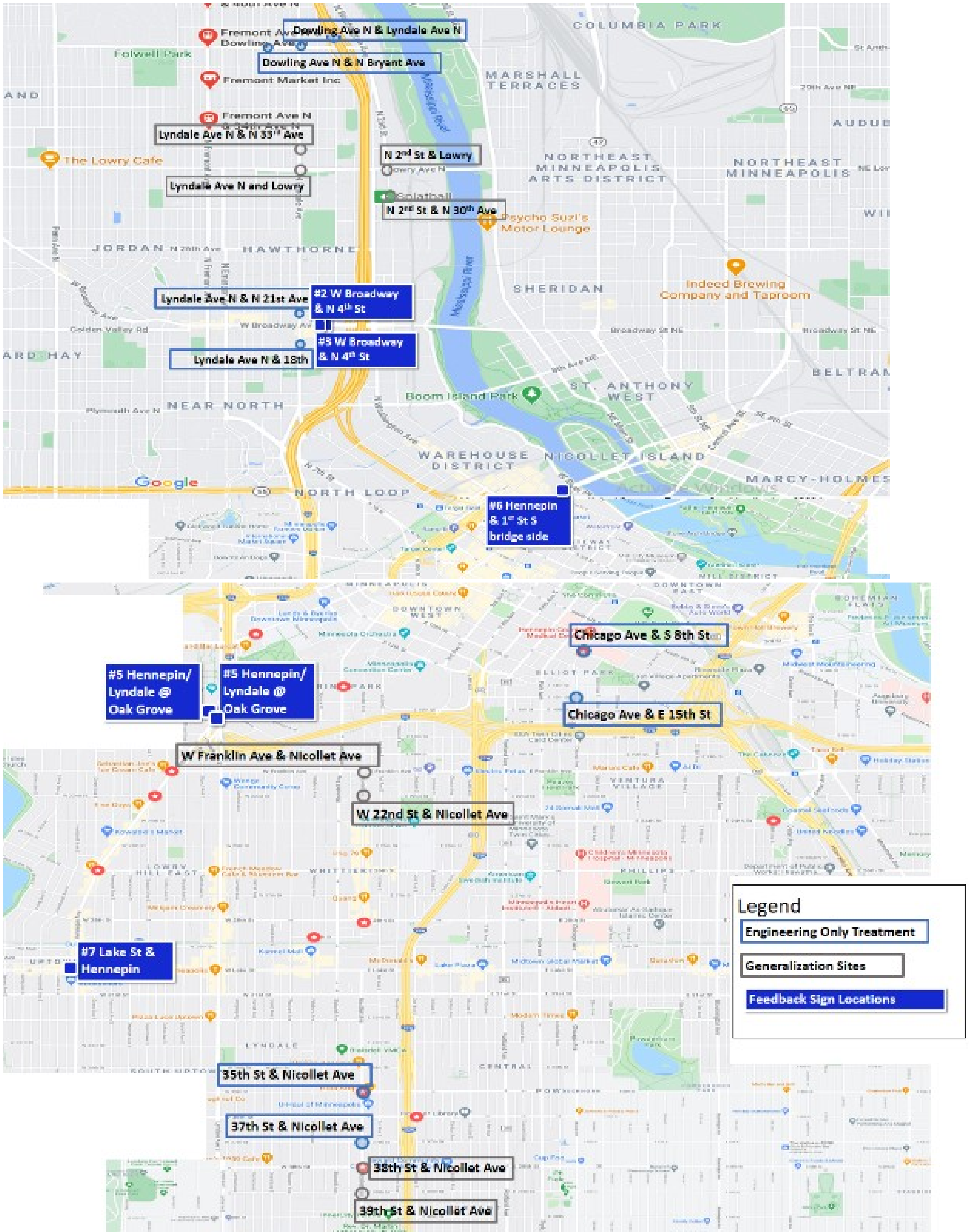


Figure 2.12 Minneapolis feedback sign locations and final study sites

2.5 PARTNERSHIP & OUTREACH

Effective implementation of engineering and social norming approaches for a community requires outreach and some degree of community buy-in. Therefore, in order to make the program successful and also establish some degree of parity to compare the effectiveness of the two interventions across the two cities, the research team performed systematic outreach to potentially interested organizations across the Twin Cities about the study. There was concurrent development of an implementation plan in collaboration with the cities of Minneapolis and Saint Paul and MnDOT.

2.5.1 Selection of Outreach Targets

The selection of stakeholders and community groups as targets for outreach were based on whether said group (a.) represented the local community close to one of the sites chosen for assessment, (b.) represented a minority group that is significantly impacted by pedestrian safety, and (c.) represented a local group in the Twin Cities interested in either pedestrian safety or transportation safety in general. For (a.), the selection of local communities was done by selecting neighborhoods or district councils that encompassed each study site in Minneapolis and Saint Paul. These selections can be seen in Table 2.18 and Table 2.19.

Table 2.19 Minneapolis sites and neighborhoods

Minneapolis Sites		Minneapolis Neighborhoods
Lyndale Ave N & Dowling Ave N	Dowling Ave N. & N Bryant Ave	Folwell
Lyndale Ave N & 18th Ave N	Lyndale Ave N & N 21st Ave	Hawthorne
Chicago Ave & S 8th St	Chicago Ave & E 16th St	Elliot Park
35th St & Nicollet Ave	37th St & Nicollet Ave	Lyndale
Lyndale Ave N & Lowry Ave	Lyndale Ave & N 33rd Ave	McKinley
N 2nd St & Lowry Ave	N 2nd St & N 30th Ave	McKinley
W Franklin Ave & Nicollet Ave	W 22nd St & Nicollet Ave	Whittier
38th St & Nicollet Ave	39th St & Nicollet Ave	King Field

Table 2.20 Saint Paul sites and district councils

Saint Paul Sites		Saint Paul District Councils
Snelling & Selby	Snelling & Laurel	Union Park
W 7th & St Clair	W 7th & Michigan	West Seventh
Cleveland Ave & Ford Pkwy	Cleveland Ave & Pinehurst Ave	Highland Park
Maryland & Arcade	Arcade & Jessamine	Payne - Phalen
Larpenteur & Rice	Larpenteur & Woodbridge	North End
University & Dale	University & Arundel	Thomas Dale / Frogtown
Maryland Ave & Rice St	Maryland Ave & Woodbridge St	North End
White Bear & Maryland Ave	White Bear & Sherwood	Greater East Side

For (b.), the selection of minority communities impacted by pedestrian safety, the research team identified African Americans, the Somali community, and the Hmong community as key groups to approach. For each of these communities, the groups selected by the research team for outreach included: The NAACP of Saint Paul and the NAACP of Minneapolis, the Confederation of Somali Community in Minnesota, the Somali Action Alliance, and the Hmong Cultural Center. For (c.), the selection of local groups generally interested in pedestrian safety in the two cities, we contacted the Pedestrian Advisory Committee of Minneapolis along with the MN Neighborhood and Community Relations, Minneapolis Parks and Recreation, and the Minnesota Safety Council.

2.5.2 Outreach Materials and Templates

The research team used separate standard email templates for whether the organization being contacted was in Minneapolis, Saint Paul, or represented a minority group or safety interests. Those templates are presented in Appendix C. The research team also presented basic information about the potential implementation plan, along with the timeline. As this was done, the research team asked for feedback about concerns and potential issues within each community represented by the group.

Finally, the research team discussed the Twin Cities pledge with the community groups, which was disseminated after the project began the intervention phase (i.e., after baseline). This pledge aimed at raising awareness of the project and eliciting media buy-in. The original materials for the pledge are presented in Appendix C. This pledge was translated into Spanish (via translation software) and Somali (via bi-lingual staff) languages. Furthermore, information about the pledge and the study was added to a custom website (https://tcsafetycup.umn.edu/) and a selection of screenshots of the website can be viewed in Appendix C.

2.5.3 Outreach Results

Outreach attempts were made for each of the organizations mentioned in section 2.5.1 Selection of Outreach Targets. For (a.), the community and neighborhood sites, there was only one response from a Minneapolis neighborhood (Hawthorne), but follow-up emails for setting up a videoconference did not elicit any further responses. For Saint Paul, all district councils responded with the exception of Greater East Side, and videoconference discussions were held with all the district councils that responded. The team gave a brief presentation to each, and all responding district councils expressed interest in the project, and a willingness to disseminate outreach materials when needed. For (b.), none of the organizations representing minority groups responded to the research team's emails, likely because these communities are meeting their members' needs during the pandemic. For (c.), non-neighborhood community organizations, the only responses were from MN Neighborhood and Community Relations and the Minnesota Safety Council. MN Neighborhood and Community Relations advised the research team via email to contact Vision Zero of Minneapolis. For the Minnesota Safety Council, the research team held a video conference with their transportation safety representative.

CHAPTER 3: DATA COLLECTION AND ANALYSIS

3.1 DATA COLLECTION METHODOLOGY

The HumanFIRST Laboratory research team collected data from the 32 selected study sites (16 in Minneapolis, 16 in Saint Paul; eight signalized and eight unsignalized in each city) from April 30th, 2021 until November 5th, 2021. By design, each site was scheduled to be visited twice a week, between the hours of 8:30 AM and 4:30 PM, to avoid rush hour traffic and maintain adequate daylight. Within morning and afternoon blocks, teams were assigned to cross study unsignalized crosswalks 20 times per visit, 10 times per coder, with any observed natural pedestrian crossing replacing a planned staged crossing. These teams also scored nearby signalized crosswalks by standing in diagonally opposite corners and counting the number of turning vehicles who did not yield for pedestrians crossing legally at the crosswalk, and the number of right-turning vehicles whose drivers looked for crossing pedestrians with an observable glance per walk cycle, for a total of 5 walk cycles per corner (20 walk cycles for an intersection). For personal safety, coders were instructed not to code during days with precipitation (rain/snow), wet roads, or if they felt the traffic was becoming too dangerous to safely cross and code at the crosswalk site. For additional safety and data quality issues, coders were instructed not to cross or collect data from sites where roadwork was being conducted (i.e., at, upstream, or downstream from crosswalk) due to the influence on traffic patterns. If scheduling permitted, the team rescheduled data collection sessions to accommodate lost data collection sessions. Major road construction on Dowling Avenue resulted in little data collection on Dowling and Fremont Avenue, resulting in a movement of that signalized site to Dowling and Lyndale Avenue. The unsignalized site that was adjacent, Dowling and Bryant Avenue, remained as a selected study site, but its designation changed from treatment to generalization in the late stages of the study. Full coding protocols are detailed in Appendix E.

3.1.1 Baseline Data Collection

The research team collected data at each study location twice a week. However, some data collection sessions were disrupted due to rain, maintenance, or unsafe conditions (e.g., unsafe traffic, nearby interpersonal conflict, or harassment of the research team). The research team conducted 243 unsignalized data collections from April 30, 2021 to July 2, 2021. In total, the team completed 4,224 staged crossings at unsignalized crosswalks during that time. The team observed 4,920 signal phases of traffic at signalized crossings during 246 coding sessions during the initial coding period.
Data collection was utilized with coding sheets for unsignalized sites and signalized sites (Appendix D). Driver behavior at unsignalized crosswalks was measured primarily using staged crossing measures, allowing for creation of conflict between drivers and staged pedestrians at the crosswalk once the drivers approach the marked dilemma zone. The dilemma zone was designed by the signal-timing formula based on roadway speed and grade of the roadway which allowed adequate time to respond to the presence of a pedestrian on the crosswalk. Driver behavior at signalized crosswalk was measured using primarily observations of turning yielding behaviors at signals, where the coding team member observed conflicts between turning drivers and pedestrians crossing during a “WALK” signal.

3.1.2 Data Collection Methods Summary

Staged crossings at unsignalized crosswalks, following the safe crossing protocol, involved the staged crosser approaching and reaching the crosswalk as vehicles were just beyond the “dilemma zone” (i.e., about 141 feet from the crosswalk on flat roads for 30 MPH) to allow adequate time for vehicles to see and respond to pedestrians. The staged crosser initiated the yield request by always planting one foot out of the street and one foot into the street, with no further movement. The staged crosser looked at oncoming vehicles. Once a driver in the first lane of traffic yielded or significantly slowed, the staged crosser waved to the motorist and fully entered the first lane of the roadway but did not proceed into further lanes until other motorists yielded or large gaps were available to where they could safely cross at a normal walking pace. The other coder would observe the behavior of approaching vehicles, score whether drivers yielded, and if so, denote the vehicle’s yielding distance from the crosswalk.

Observation sessions at signalized crosswalks, following a newly developed protocol, involved the pair of research team observers standing diagonally at the opposing corners of the intersection, with one street marked as the “major” corridor and the other street marked as the “minor” corridor. The research team would stand near the crosswalk of the intersection as if prepared to cross counterclockwise around the intersection, acting as a distractor or “dummy” pedestrian to elicit looking behavior from turning drivers. When the green light would initiate the cycle, the research team would remain in place on the opposing corners of the intersection and watch vehicles turning right to see if the driver looked or glanced toward them to determine whether the turn was safe for potential crossing pedestrians. Drivers who did not look were scored as “not looking” and drivers who looked were scored as “looking”. Furthermore, if natural pedestrians crossed at any of the crosswalks, the observing team member that was present on the adjacent crosswalk would score if any right or left-turning vehicles yielded or did not yield to the pedestrian. Looking behavior did not yield conclusive findings and was not included in final analyses, but summarized data is included in Appendix F.

After 5 walk cycles, the observing team would rotate corners to cover the other street, while also observing turning vehicles to see if the vehicles yielded while the research team members transitioned to the next corner. This led to 10 walk cycles observed per team member, and 20 total walk cycles observed for the intersection per site visit.

3.1.3 Data Collection by Site

Table 3.1 and Table 3.2 outline the frequency of data collection sessions over the measurement period and the total number of crossings (i.e., both staged and natural crossings) measured at each study site. In total, 686 unsignalized data collection sessions (354 in Minneapolis, 332 in Saint Paul) were conducted. Slightly more site visits were performed for unsignalized sites in Minneapolis in early November to capture any potential effects of R1-6 signs implemented in Minneapolis in mid-October 2021. Additionally, for unsignalized sites, the total number of crossings (i.e., including both staged crossings and natural pedestrian crossings) conducted over the study period was 11,893 crossings. There were 675 signalized data collection sessions (338 in Minneapolis, 337 in Saint Paul) over the study period. For signalized sites, the total number of walk cycles observed over the study period was 12,841 cycles.

Table 3.1 Data collection count by session and crossing by unsignalized sites

Site	City	Treatment/ Generalization	Total Data Collection Sessions	Total Crossings
2nd & 30th	Minneapolis	Generalization	44	715
Dowling & Bryant	Minneapolis	Generalization	45	793
Lyndale & 33rd	Minneapolis	Generalization	45	787
Nicollet & 22nd	Minneapolis	Generalization	42	749
Nicollet & 39th	Minneapolis	Generalization	46	805
Chicago & 15th/16th	Minneapolis	Treatment	43	740
Lyndale & 21st	Minneapolis	Treatment	44	695
Nicollet & 37th	Minneapolis	Treatment	45	798
		Minneapolis Total	**354**	**6,082**
7th & Michigan	Saint Paul	Generalization	45	817
Maryland & Woodbridge	Saint Paul	Generalization	40	707
University & Arundel	Saint Paul	Generalization	43	772
White Bear & Sherwood	Saint Paul	Generalization	38	594
Arcade & Jessamine	Saint Paul	Treatment	40	677
Cleveland & Pinehurst	Saint Paul	Treatment	44	805
Larpenteur & Woodbridge	Saint Paul	Treatment	41	718
Snelling & Laurel	Saint Paul	Treatment	41	721
		Saint Paul Total	**332**	**5,811**
		Grand Total (Minneapolis and Saint Paul)	**686**	**11,893**

Table 3.2 Data collection count by sessions by signalized sites

Site	City	Treatment/ Generalization	Total Data Collection Sessions	Total Crosswalk Cycles
Dowling & Freemont/Lyndale	Minneapolis	Generalization	38	780
Franklin & Nicollet	Minneapolis	Generalization	43	824
Lowry & 2nd	Minneapolis	Generalization	44	902
Lowry & Lyndale	Minneapolis	Generalization	44	890
Nicollet & 38th	Minneapolis	Generalization	45	853
Chicago & 8th	Minneapolis	Treatment	41	513
Lyndale & 18th	Minneapolis	Treatment	41	837
Nicollet & 35th	Minneapolis	Treatment	42	613
		Minneapolis Total	**338**	**6,212**
7th & St Clair	Saint Paul	Generalization	42	854
Maryland & Rice	Saint Paul	Generalization	46	926
Maryland & White Bear	Saint Paul	Generalization	41	810
University & Dale	Saint Paul	Generalization	43	746
Arcade & Maryland	Saint Paul	Treatment	40	794
Ford & Cleveland	Saint Paul	Treatment	41	827
Larpenteur & Rice	Saint Paul	Treatment	42	813
Snelling & Selby	Saint Paul	Treatment	42	859
		Saint Paul Total	**337**	**6629**
		Grand Total (Minneapolis and Saint Paul)	**675**	**12,841**

3.2 DATA ANALYSIS OVERVIEW

The data analysis of the study consists of two major analyses. The objective of the primary analysis was to examine the efficacy of a multi-phased community intervention program that aimed to promote driver compliance with the Minnesota Crosswalk Law at high-risk urban intersections in Saint Paul and Minneapolis. The program incorporated implementations of various types of engineering countermeasures, along with the community feedback signs regarding stopping percentages, deployed at select locations in the vicinity of study sites.

A total of seven unsignalized intersections and seven signalized intersections were identified as the treatment intersections. For each intersection type, there were four treatment sites in Saint Paul and three treatment sites in Minneapolis. Eighteen intersections that had similar roadway and intersection characteristics, such as ADT, the number of lanes, posted speed limit, etc., were identified as generalization sites (i.e., no direct treatments were applied at these sites, but broader community treatments could have potentially generalized to them). The outcome of interest in the current analysis focused on identifying any improvements on drivers' performance on stopping for pedestrians (or yielding performance), comparing treatment and generalization sites before and after the intervention, for each intersection type, and within each city.

The objective of the secondary analysis was to evaluate how community members' perceptions of pedestrian safety differed based on which city they lived in and over time. The analysis involved comparing survey responses of residents from both Minneapolis and Saint Paul from two online surveys which were administered in two phases, i.e., before and after the implementation of the intervention program. The survey questions of this project were concerned with:

1. Respondents' self-reported frequencies of driving and crossing in crosswalks in both cities
2. Perceived risks for different types of crosswalks in both cities
3. Knowledge of the Minnesota crosswalk law
4. Awareness of the community intervention program, including the community feedback signs

3.3 EVALUATION OF THE COMMUNITY ENGINEERING & OUTREACH INTERVENTION PROGRAM

3.3.1 Community Engineering & Outreach Intervention Research Questions

The following session provided evaluations on drivers' yielding outcomes at unsignalized and signalized intersections. Different analytical approaches were utilized with each intersection type, which focused on addressing four research questions:

1. Did the outcome differ between the two cities and over time?
2. How effective were the feedback signs in changing drivers' stopping for (or yielding to) pedestrians in crosswalks?

3. How well did engineering countermeasures work on improving drivers' stopping frequency at various interim stages of the program implementation?
4. As one integrated program, did the community intervention efforts (including feedback signs and all engineering countermeasures) improve the percentage of drivers stopping for pedestrians?

3.3.2 Evaluation of Program Performance at Unsignalized Intersections

The primary analysis is divided into two examinations of the treatment effectiveness. The first examined the treatments applied to the unsignalized intersections in both the cities of Minneapolis and Saint Paul. The overview of the types of treatments and the schedule of deployment of the treatments are shown in Figure 3.1. An image of each treatment and the associated locations of the treatments are shown in Table 3.1. The second examined treatments applied to signalized intersections, detailed in Section 3.3.3.

3.3.2.1 Overview of Engineering Countermeasures at Unsignalized Intersections

UNSIGNALIZED INTSERSECTION EVALUATION APPROACH

DIFFERENCES-IN-DIFFERENCE SPECIFICATION

The "Differences-in-Difference" (or DID) analytical approach was proposed to examine the effectiveness of the intervention in improving driver compliance to the Minnesota Crosswalk Law. This method compared the difference in the study outcomes (e.g., percentage of stopping for pedestrians) between the treatment intersections and generalization sites during the same period, before and after the implementation of the intervention. One critical assumption to ensure the internal validity of the DID models is the "parallel trend assumption". Although the intervention and generalization groups may have different levels of the outcome before the intervention is implemented, this assumption requires that their trends in pre-intervention outcomes should hold constant over time (i.e., parallel). Failure to satisfy this assumption can lead to biased estimations of the treatment effect using DID models.

SELECTION OF EVALUATION APPROACH AND INITIAL DATA MANAGEMENT

In the current project, there were considerable variations in the types of countermeasures and their corresponding implementation times across all intervention intersections, regardless of the intersection type. The temporal trend of weekly yielding outcomes (i.e., the percentage of drivers stopping for pedestrians) was assessed during the pre-treatment period for the parallel trend at both unsignalized and signalized intersections within each city. Additionally, empirical knowledge of each intervention site during data collection was also provided, including the post-intervention maintenance of a specific countermeasure or any unexpected events that might have potentially influenced the treatment measurement.

The DID approach was appropriate for analyzing unsignalized intersections based on inspections of the temporal trend of outcome differences between the intervention and generalization groups at baseline (i.e., before the start of any engineering intervention or feedback sign). Specifically, the initial 3 weeks of data (i.e., week 0 to week 2, see Figure 3.2) were removed from the present analyses for unsignalized intersections in both cities. These weeks capture data collected from Minneapolis locations prior to or just after crosswalk markings being installed. This difference in intersection treatment between the two cities made them far more difficult to compare. The exclusion of these data allows a more balanced comparison between the two cities after the crosswalk markings in Minneapolis appeared to have resulted in an initial stabilization in driver responses to the markings.

UNSIGNALIZED INTERSECTION DATA ANALYSIS METHOD

At unsignalized intersections, the overall yielding percentage was the primary focus, which was treated as a continuous outcome. Descriptive statistics were provided at each intervention and generalization site and averaged over the intersection groups at different treatment stages. To address the research questions, an overall analysis was conducted to examine the general differences in outcomes between the two cities and over time, followed by stratified analyses to evaluate the average treatment effect of countermeasures within each city.

Overall Differences of Outcome between the Two Cities and Over Time. The initial analysis is an aggregated analysis of the outcome, which included *City* (i.e., Saint Paul or Minneapolis) and *Week* (i.e., indicating the *n*th week of data collection) as predictors in the model. The goal of this analysis was to determine overall differences between cities and if drivers' stopping outcomes would change by time in general, when averaging across both intervention and generalization intersections.

Effect of the Feedback Signs in Each City. Data collection periods before and after the launch of the feedback signs (i.e., relevant cut-off weeks) were coded as 0 and 1 for a binary variable of the feedback sign implementation time, respectively, with analyses stratified by each City. Only generalization sites were included for analyzing the effect of feedback signs because engineering interventions also affected treatment sites.

Treatment Effect of the Interim Interventions during Various Treatment Stages in Each City. Using the DID analysis approach, the treatment effect of any precedent and current countermeasures during a specific interim treatment stage of the program implementation could be obtained. Dependent variables included the *Intervention group* (i.e., an intervention or generalization intersection) and *Time of intervention* (i.e., 0 = pre-treatment or 1 = post-treatment). For a specific interim treatment stage, the post-treatment period started in the first week of new countermeasure initiations during this stage and ended at the start of the following stage.

Treatment Effect of the Integrated Community Intervention Program in Each City. Similarly, the DID approach was also utilized for evaluating the overall effectiveness of the community intervention program, as an integrated program. In this analysis, the post-treatment period included data collection weeks at and after all treatments were implemented (i.e., the final treatment stage).

To summarize, the pre-treatment period was identified as the same baseline period in all DID models for estimating the average treatment effect, regardless of which interim or final treatment stage was investigated. This set-up allows a stable composition of the treatment and generalization groups during the pre-treatment period, as well as the satisfaction of the parallel trend assumption. A significant and positive effect associated with the interaction term of *Intervention* and *Time of intervention* would likely indicate improvement in performance across time of intervention for treatment intersection sites compared to generalization sites (i.e., differences in difference) if found.

UNSIGNALIZED INTERSECTION STATISTICAL ANALYSIS

Multivariate analyses, along with the Generalized Estimating Equations (GEEs), were utilized to analyze the average treatment effect at unsignalized intersections. The exchangeable correlation matrix was applied in the models to account for the correlations within repeated measures on the same intersection. Linear regressions were used to estimate the mean difference across different levels of predictors and corresponding 95% CIs were provided using Tukey-Kramer tests for multiple comparisons. *The result was significant if the 95% CIs of the mean difference did not include the value of zero.*

Important covariate variables were also accounted for in the models for analyzing unsignalized intersections in each city, including the major road ADT (i.e., log (ADT)), the number of lanes on the major road (i.e., four-lane versus two-lane road), presence of shoulder (i.e., yes versus no), the length of major road crosswalk length (in feet), and the length of the minor crosswalk (in feet). The major crosswalk refers to the crosswalk intersecting the roadway with greater observed traffic volume, and the minor crosswalk the crosswalk intersecting the roadway with lesser observed traffic volume. Due to minimal variations across the treatment and generalization groups, the number of lanes on the major road and the presence of shoulders were not included in the analyses of unsignalized intersections in Minneapolis. All statistical analyses were performed using the SAS software version 9.4.

ENGINEERING COUNTERMEASURES AT UNSIGNALIZED INTERSECTIONS RESULTS

DIFFERENCES OF OUTCOME BETWEEN THE TWO CITIES AND OVER TIME

Overall, there was a significant main effect of City (χ^2 = 6.70, p = 0.010). The yielding percent was significantly higher in Saint Paul (*M* = 41.8%, *SD* = 19.7%), compared to that in Minneapolis (***M* = 24.8%, *SD* = 14.6%; Mean difference = 16.7%, 95% CI = [5.3%, 28.2%]**). However, there was no observed significant temporal effect on the yielding percentage. Also see Figure 3.1 for the trends of the weekly average for yielding percentages at unsignalized locations across two cities.

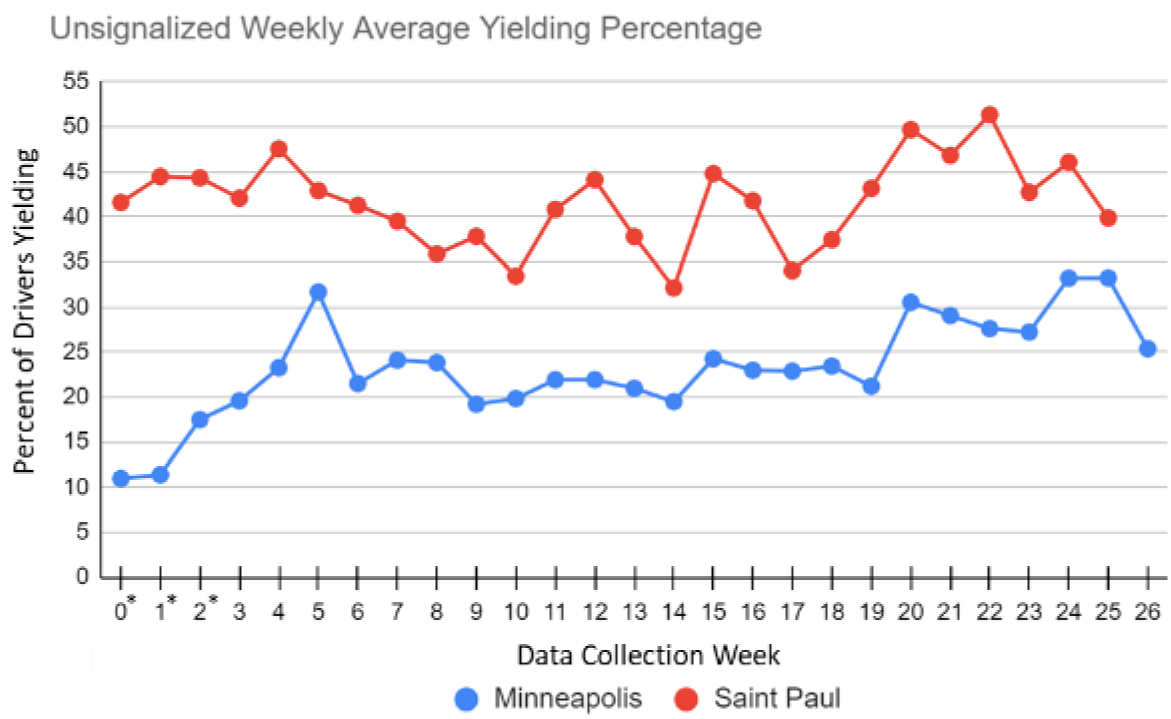


Figure 3.1 Weekly average for yielding at unsignalized locations across two cities (*weeks excluded from analysis) with

UNSIGNALIZED INTERSECTIONS IN SAINT PAUL

SAINT PAUL UNSIGNALIZED INTERSECTIONS DESCRIPTIVE STATISTICS

Four different time periods were generated and evaluated based on the implementation schedule of intervention countermeasures in Saint Paul (also see Table 3.3 for the data categorization). See Figure 3.2 for the implementation timeline. The baseline period included 7 weeks of data collection ranging from week 3 to week 9, prior to the start of the feedback signs during week 10 (i.e., 07/13/2021). Following the baseline period, two interim treatment stages were administered. The first interim treatment stage included 7 weeks of data collection ranging from week 10 to week 15 (i.e., before 8/26/2021). The intervention initiated during this period consisted of the feedback signs, stop bars, and repainted crosswalks at corresponding treatment sites. The second interim treatment stage ranged from week 16 to week 20 of data collection, during which the R1-6 signs were implemented at all four treatment sites. In addition, bollards were installed along with the R1-6 signs at the intersection of "Larpenteur & Woodbridge". The final treatment stage included 6 weeks ranging from week 21 to week 26 of data collection (i.e., after 09/28/2021). During this period, additional R1-6 signs were implemented at two intersections of "Larpenteur & Woodbridge" and "Snelling & Laurel".

Table 3.3 A summary table of the mean yielding percentage (n of data points in parentheses) at each unsignalized intersection in Saint Paul during different treatment stages

Saint Paul Unsignalized Sites	Baseline Period	Interim Treatment Stage 1	Interim Treatment Stage 2	Final Treatment Stage
Treatment Sites				
Arcade & Jessamine	33.2% (12)	20.4% (10)	53.9% (7)	52.7% (9)
Cleveland & Pinehurst	67.2% (14)	70.7% (12)	63.1% (5)	84.8% (10)
Larpenteur & Woodbridge	47.6% (12)	38.7% (10)	42.9% (7)	56.8% (9)
Snelling & Laurel	42.0% (14)	53.1% (11)	44.9% (7)	**33.1% (6)***
Generalization Sites				
7th & Michigan	44.2% (14)	40.5% (12)	43.8% (6)	34.2% (10)
Maryland & Woodbridge	33.4% (11)	30.4% (10)	25.1% (7)	26.7% (8)
University & Arundel	33.2% (14)	33.3% (11)	35.7% (5)	37.8% (10)
White Bear Ave & Sherwood	28.0% (12)	20.4% (10)	27.4% (7)	24.5% (8)

Note. Items asterisked were excluded from final analysis due to observed issues at the site.

Observations from field data collection indicated that the R1-6 signs had survivability issues at the intersection of “Snelling & Laurel”. The additional sign treatment was damaged shortly after installation, leaving only one sign present. Additionally, due to construction work north of the location, one lane of the major road was regularly closed during the final treatment stage at this intersection. The construction often resulted in traffic backups which influenced the study location. As shown in Table 3.2, there was a noticeable decrease in the average yielding percentage at “Snelling & Laurel” when comparing between the final treatment stage and baseline (See Table 3.2, 33.1% versus 42.0%); however, a reversed trend was found at each of the other three treatment sites (See Table 3.2). The influences of these factors on the outcome during data collection could have erroneously been attributed to the treatment effect, which may lead to biased estimations if included in the model. As a result, the final 6 weeks of data at “Snelling & Laurel” were excluded from the analyses (See Table 3.2, in bold and asterisk).

Figure 3.3 provides the average yielding percentage by group and by treatment stage, when excluding the final weeks of data at “Snelling & Laurel”. As illustrated in this figure, the difference of the yielding percentage between treatment and generalization sites during each interim treatment stage had little variability when compared to the outcome difference at baseline (i.e., Figure 3.3, 48.1% versus 35.1%). However, a much greater elevation of the yielding percentage was observed at treatment sites during the final treatment stage than baseline, compared to that at generalization sites (i.e., Figure 3.2, 65.5% versus 48.1%, compared to 31.4% versus 35.1%). The following inferential analyses provided tests to determine if any of these “Differences-in-difference” was statistically significant, after adjusting for relevant covariate variables.

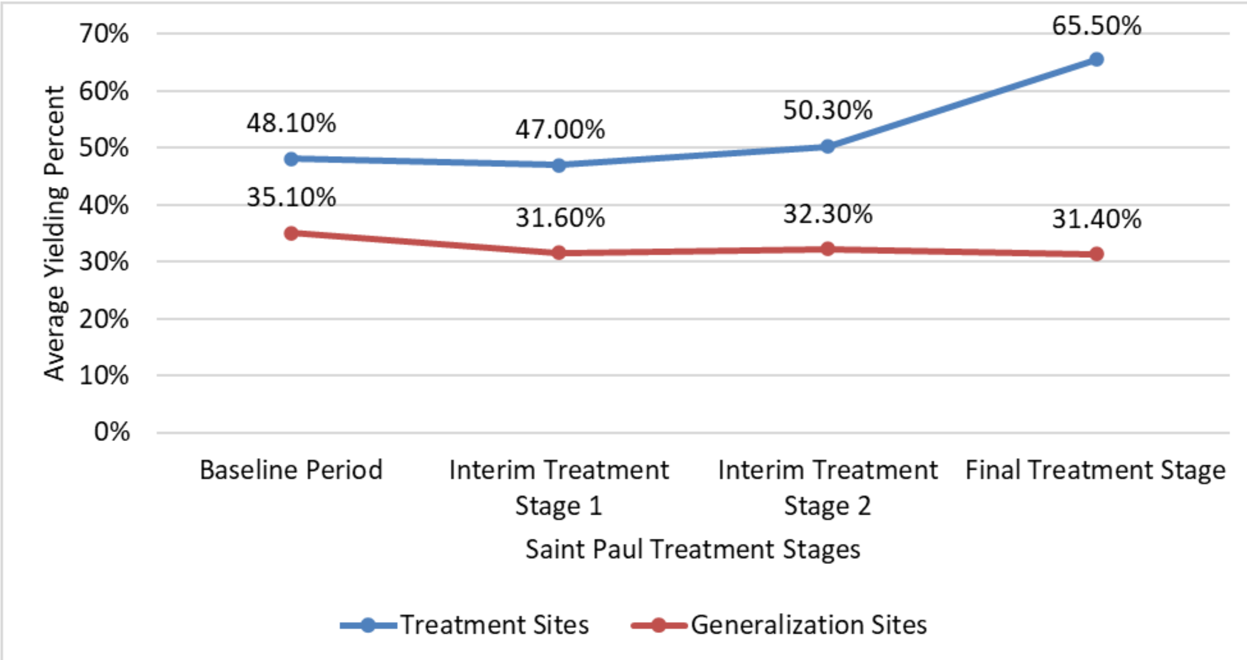


Figure 3.2 Average yielding percentage by group and by treatment stage in Saint Paul

SAINT PAUL UNSIGNALIZED INTERSECTIONS INFERENTIAL STATISTICAL ANALYSIS RESULTS

Effect of the Feedback Signs in Saint Paul: Among all unsignalized generalization intersections, a slightly lower average yielding percent was found after the community feedback signs were implemented (i.e., week 10 and after, *M* = 31.7%, *SD* = 14.2%), compared to that during the pre-treatment period (i.e., baseline, *M* = 35.1%, *SD* = 12.6%). The estimated difference of yielding percent at unsignalized intersections was not statistically significant, associated with the feedback signs, $\chi^2 = 1.95$, $p = 0.163$.

Treatment Effect of the Interim Interventions during Stage 1: The treatment effect of the interim interventions at stage 1 was not statistically significant ($\chi^2 = 2.66$ for the interaction term, $p = 0.103$), when comparing the pre-post difference of the yielding percentage between treatment and generalization site groups. At treatment sites alone, there was a slight reduction in the average yielding percentage during the interim treatment stage 1 compared to baseline (Mean Difference = -1.2%, 95% CI = [-13.3%, 10.9%], $p = 0.994$). The pre-post difference of outcome was not statistically significant at generalization sites.

Treatment Effect of the Interim Interventions during Stage 2: Similarly, there was no statistically significant treatment effect associated with the second stage of interim interventions ($\chi^2 = 1.18$ for the interaction term, $p = 0.278$). At treatment sites alone, the mean yielding percentage slightly increased during the interim treatment stage 2 compared to baseline; however, this increase was not statistically significant (Mean Difference = 3.8%, 95% CI = [-9.5%, 17.1%], $p = 0.880$). The pre-post difference of outcome was not statistically significant at generalization sites.

Treatment Effect of the Integrated Community Intervention Program: There was a statistically significant overall treatment effect associated with the entire program (**χ^2 = 4.52 for the interaction term, *p* = 0.034**). At treatment sites alone, the average yielding percent significantly increased after the entire program was implemented, compared to the period that had an absence of any treatment (i.e., baseline), **Mean Difference = 14.6%, 95% CI = [8.0%, 21.3%], *p* < .001**. The pre-post difference of outcome was not statistically significant at generalization sites, Mean Difference = -3.8%, 95% CI = [-11.4%, 3.8%], *p* = 0.582.

Other Covariates: None of the associations between the outcome and covariate variables were statistically significant in the above analyses for examining the average treatment effect of countermeasures during any treatment stage of the program implementation.

UNSIGNALIZED INTERSECTIONS IN MINNEAPOLIS

SAINT PAUL SIGNALIZED INTERSECTIONS DESCRIPTIVE STATISTICS

Two stages of intervention countermeasures were considered at signalized intersections in Saint Paul. The interim treatment stage 1 included week 11 to week 20 of data collection, which involved the implementation of the community feedback signs, repainted crosswalks, and "Stop for Pedestrians" signs. In week 21, the hardened centerlines started to be implemented at "Larpenteur Ave W & Rice St", followed by additional initiations of the hardened centerlines and painted stop bars at the remaining three treatment intersections. Thus, data on and after week 21 were treated as the final treatment stage. Table 3.4 summarizes the right and left-turning yielding percentage at each signalized intersection in Saint Paul, during the baseline period and the identified treatment stages.

Table 3.4 A summary table of the right and left-turning yielding percentage (n of data points in parentheses) at each signalized intersection in Saint Paul during different treatment stages

	Right-turning yielding			Left-turning yielding		
	Baseline Period	**Interim Treatment Stage 1**	**Final Treatment Stage**	**Baseline Period**	**Interim Treatment Stage 1**	**Final Treatment Stage**
Treatment Sites						
Arcade & Maryland	82.8% (17)	97.8% (15)	83.3% (12)	68.8% (8)	57.1% (7)	90.0% (5)
Ford & Cleveland	91.4% (31)	92.6% (28)	85.4% (18)	65.8% (26)	94.4% (22)	88.3% (15)
Larpenteur & Rice	81.5% (18)	78.8% (22)	83.3% (12)	63.9% (12)	78.6% (14)	81.3% (8)
Snelling & Selby	93.9% (26)	94.5% (21)	90.8% (13)	91.7% (14)	73.4% (21)	75.0% (8)
Generalization Sites						
7^{th} & St Clair	85.4% (16)	86.4% (11)	71.4% (7)	72.6% (14)	90.0% (15)	72.2% (9)
Maryland & Rice	93.3% (15)	75.0% (18)	90.7% (9)	84.6% (13)	70.8% (12)	100% (1)
Maryland & White Bear Ave	86.4% (11)	100% (15)	75.0% (8)	73.1% (13)	72.2% (9)	58.3% (4)
University & Dale	85.4% (22)	94.7% (11)	78.4% (18)	47.7% (11)	83.3% (6)	62.5% (12)

Figure 3.3 illustrates the distributions of right-turning yielding compliance levels (1 through 5) at both treatment and generalization signalized intersections in Saint Paul. Compared to baseline, the yielding performance at treatment sites appeared to be slightly improved during the interim treatment stage 1, but not during the final treatment stage. However, a greater decline in the yielding performance may be observed at generalization sites, as reflected by a much smaller proportion in the highest compliance level (i.e., stopping for pedestrians during 90% of the time and above), when comparing the final treatment stage to the baseline period.

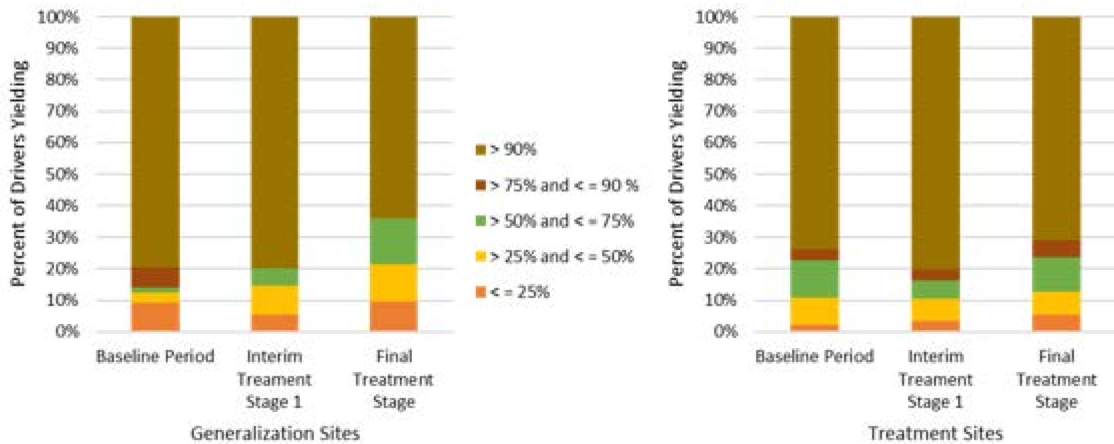


Figure 3.3 Distributions of right-turning yielding compliance levels at signalized generalization and treatment intersections in Saint Paul

Also as shown in Figure 3.4, although in general slightly better left-turning yielding performance were observed at treatment sites than at generalization sites, the differences in distributions of the yielding compliance levels did not appear to vary across the two groups and over time.

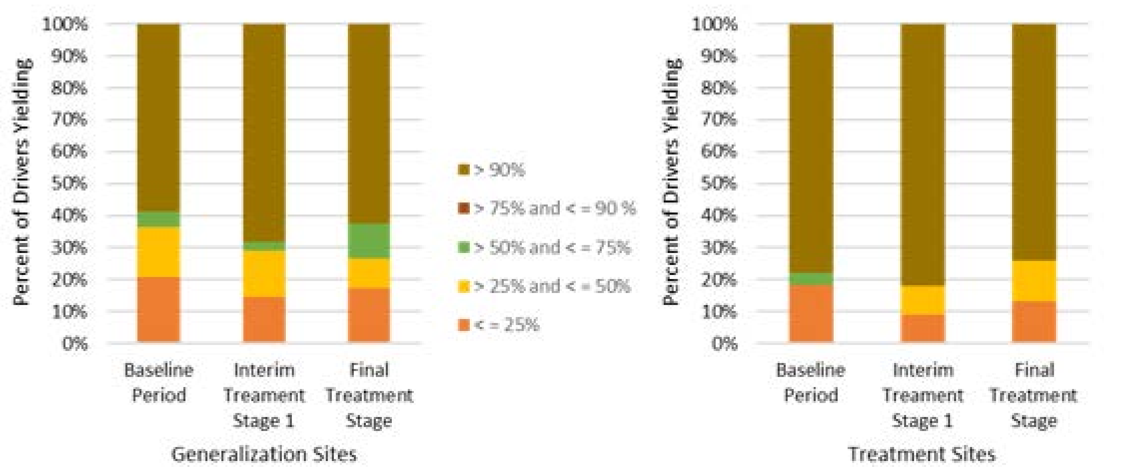


Figure 3.4 Distributions of left-turning yielding compliance levels at signalized generalization and treatment intersections in Saint Paul

MINNEAPOLIS UNSIGNALIZED INTERSECTIONS DESCRIPTIVE RESULTS

A similar relatively stable period of baseline data was identified for the unsignalized intersections in Minneapolis, ranging from week 3 to week 7 of data collection (i.e., parallel trend). During this initial baseline period, the average yielding percent was higher at the generalization than treatment sites (likely due to the relatively high yielding percentage at the intersection of "2nd & 30th"; see Table 3.5). However, it was also interesting to find that the direction of trends in outcome differences shifted between the two groups, where the yielding percentage increased at most treatment intersections and decreased at generalization sites starting from week 8 (See Table 3.5).

Table 3.5 A summary table of the mean yielding percentage (n of data points in parentheses) at each unsignalized intersection in Minneapolis during different treatment stages

Minneapolis Unsignalized Sites	Baseline Period	Interim Treatment Stage 1	Interim Treatment Stage 2	Interim Treatment Stage 3	Final Treatment Stage
Treatment Sites					
Nicollet & 37th	19.8% (11)	32.9% (4)	22.7% (12)	29.5% (7)	38.8% (8)
Chicago & 15th/16th	25.5% (10)	32.6% (4)	35.9% (12)	41.4% (6)	46.6% (8)
Lyndale & 21st	14.0% (10)	15.2% (4)	12.8% (11)	11.5% (8)	31.0% (8)
Generalization Sites					
2nd & 30th	48.3% (9)	36.3% (5)	40.1% (11)	42.0% (8)	48.6% (8)
Dowling & Bryant	15.9% (11)	10.3% (5)	12.4% (11)	19.7% (8)	14.3% (7)
Lyndale & 33rd	19.9% (10)	12.9% (5)	21.0% (12)	21.4% (8)	17.5% (7)
Nicollet & 22nd	24.5% (11)	11.6% (3)	13.7% (9)	21.5% (7)	13.2% (8)
Nicollet & 39th	25.2% (11)	18.6% (4)	16.8% (12)	29.5% (8)	28.4% (8)

While there were not any new engineering countermeasures during week 8 to week 10, this period was treated as the interim treatment stage 1 for analysis purposes, due to observed shifts in yielding patterns across the two site categories (i.e., treatment and generalization). The increase is hypothesized to be the result of the installation of new or repainted crosswalks during weeks 3 and 4. The driver behavioral change to these installations may have been carried over and continued into weeks 5 through 7 at unsignalized intersections in Minneapolis. It is possible that drivers were cued by the presence of markings as well as increased numbers of pedestrians crossing at those locations (i.e., more pedestrians may have begun to cross there following the markings), as drivers will be more likely to yield if they are expecting pedestrians in that location. Other unmeasured environmental and social factors that could affect the safe driving culture in Minneapolis or specific to the local community might also have contributed to the observed direction change of the yielding percentage.

Following that, the interim treatment stage 2 was identified, ranging from week 11 to week 17 of data collection. The intervention initiated during this period consisted of the feedback signs (i.e., near the beginning of week 11) in the community, as well as bollards at two intervention sites. From week 18 to week 22, the third interim treatment stage involved the implementation of lane conversion and bump-outs at the intersection of "Lyndale & 21st" alone. Additionally, the final treatment stage ranged from week 23 and after. The intervention countermeasures initiated included R1-6 signs at two treatment intersections and bollards and pedestrian refugees at one treatment intersection.

A similar trend in the outcome differences across the two groups was also illustrated in Figure 3.5, during different stages of the program implementation. At baseline, the average yielding percentage of the generalization group was lower than the treatment group (i.e., 19.8% versus 26.0%). However, the direction was reversed starting from interim treatment stage 1, until a much greater difference in outcome between the two groups was found during the final treatment stage (i.e., 38.8% versus 24.9%).

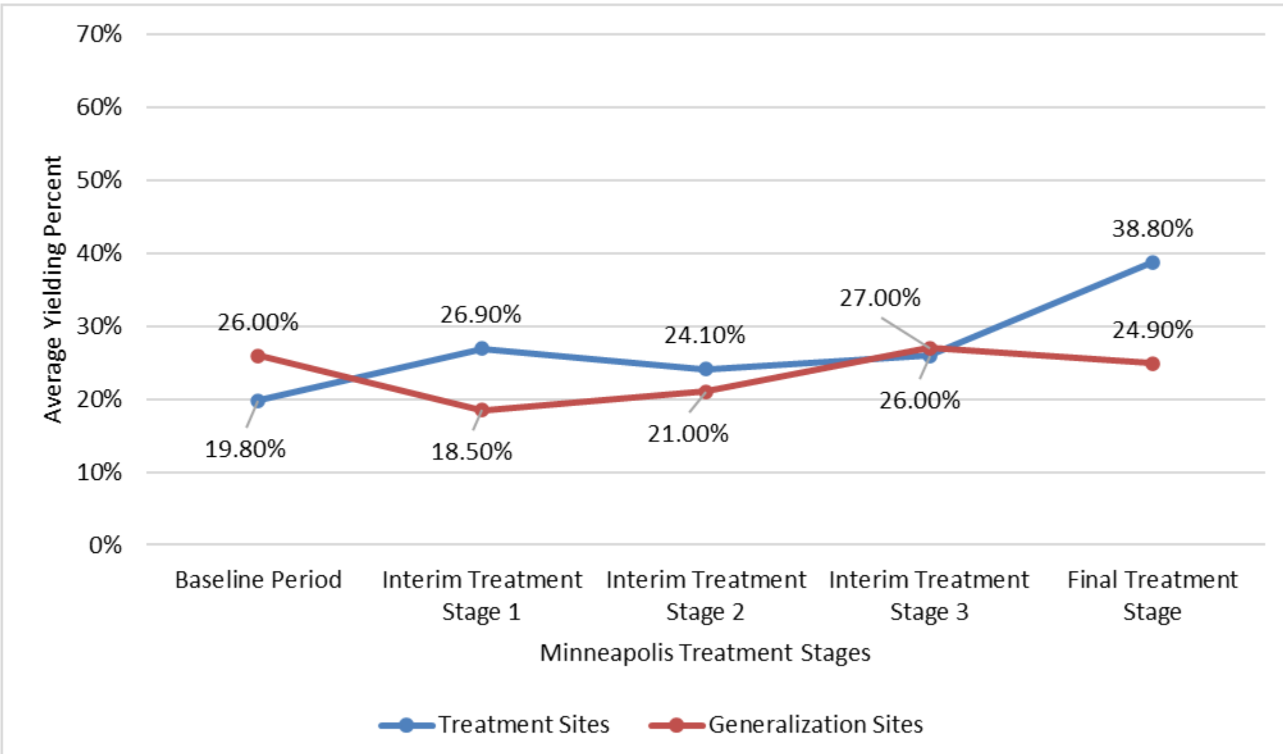


Figure 3.5 Average yielding percentage by group and by treatment stage in Minneapolis

MINNEAPOLIS UNSIGNALIZED INTERSECTIONS INFERENTIAL ANALYSES RESULTS

Effect of the Feedback Signs in Minneapolis: Among all unsignalized generalization intersections in Minneapolis, the average yielding percentage after the community feedback signs were implemented at week 11 and after (M = 23.9%, SD = 14.2%) was not statistically different from that before week 11, M = 23.8%, SD = 14.5%, χ^2 = 0.13, p = 0.723.

Treatment Effect of the Interim Interventions during Stage 1: The treatment effect of the interim interventions at stage 1 was statistically significant (**χ^2 = 4.92 for the interaction term, p = 0.027**), when comparing the pre-post difference of the yielding percentage between treatment and generalization groups. There was a 7.1% increase in the yielding percentage at treatment sites (Mean Difference =

7.1%, 95% CI = [-0.1%, 14.2%], p = 0.052, borderline), whereas at generalization sites, the yielding percentage *significantly decreased* by 8.7% (**Mean Difference = 8.7%, 95% CI = [-12.1%, -5.3%], p < .001**)

Treatment Effect of the Interim Interventions during Stage 2: The effect associated with interventions during the second interim treatment stage also appeared to be important, yet it was not statistically significant (χ^2 = 3.72 for the interaction term, p = 0.054, borderline). Compared to baseline, the mean yielding percentage during the interim treatment stage 2 slightly increased at treatment sites (Mean Difference = 4.1%, 95% CI = [-2.9%, 11.1%], p = 0.433), and *significantly decreased* at generalization sites (**Mean Difference = -5.9% 95% CI = [-10.9%, -0.9%], p = 0.012**).

Treatment Effect of the Interim Interventions during Stage 3: There was no statistically significant treatment effect associated with interventions during the third interim treatment stage (χ^2 = 1.55 for the interaction term, p = 0.214). Compared to baseline, an elevated yielding percentage was found at treatment sites during this stage (Mean Difference = 6.9%, 95% CI = [-4.6%, 18.3%], p = 0.410). The pre-post difference of outcome at generalization sites was minimal, and not statistically significant.

Treatment Effect of the Integrated Community Intervention Program: There was a statistically significant overall treatment effect associated with the entire program (**χ^2 = 5.83 for the interaction term, p = 0.016**). At treatment sites, the average yielding percent significantly increased after the entire program was implemented, compared to that in the absence of any treatment (i.e., baseline) (**Mean Difference = 18.9%, 95% CI = [16.4%, 21.4%], p < .001**). Compared to baseline, the yielding percentage decreased by 2.4% during the final stage at generalization sites, yet the result was not statistically significant (Mean Difference = -2.4%, 95% CI = [-8.3%, 3. %], p = 0.726).

Other Covariates: Like the results in Saint Paul, there were no statistically significant associations between the outcome and covariate variables in the models for examining the average treatment effect of countermeasures at unsignalized intersections in Minneapolis.

SUMMARY OF RESULTS AT UNSIGNALIZED INTERSECTIONS

The results of program evaluations at unsignalized intersections in the present project are summarized below:

- Overall, the study outcome significantly differed between the two cities, but not by time. The yielding percentage was estimated to be 16.7% greater in Saint Paul than in Minneapolis, when averaging across all treatment and generalization unsignalized intersections (i.e., M = 41.8% versus M = 24.8%, respectively).
- The feedback signs appeared to be less effective in changing drivers' stopping for (or yielding to) pedestrians in crosswalks at unsignalized intersections, regardless of city.

Specific to unsignalized intersections in Saint Paul:

- The implementation of the integrated community intervention program significantly improved drivers' stopping (or yielding) behaviors at unsignalized intersections (**χ^2 = 4.52 for the interaction term, p = 0.034**). Compared to baseline, the yielding percentage at treatment sites increased by an estimate of 14.6% after all countermeasures were implemented (i.e., *M* = 65.5% versus *M* = 48.1%), whereas at generalized sites, there was a 3.8% decrease in the yielding percentage during the same post-treatment period (i.e., *M* = 31.4% versus *M* = 35.1%).
- Although the effect of interventions was not significantly associated with the interim treatment stages, the program appeared to positively impact drivers' yielding performance in a progressive manner. This manner may be reflected by a continuously increasing trend in the outcome differences between treatment and generalization groups, along with the phased implementation of the program.
- The R1-6 signs introduced at the final treatment stage appeared to demonstrate the most potential in improving drivers' yielding percentage at relevant treatment sites in Saint Paul. However, the potential continuing (or delayed) protective effects of all other existing interventions implemented during the precedent interim treatment stages should also be considered in conjunction with any new countermeasure, because their effects cannot be parsed out easily in this study.
- The effectiveness of countermeasures may vary at individual treatment sites, due to various observed external factors (e.g., construction work at "Snelling & Laurel") and unobserved factors. It is recommended that proper maintenance or exploration of alternative robust sign designs to improve survivability be considered, as this is essential to obtain the intended efficacy of any intervention.

Specific to unsignalized intersections in Minneapolis:

- There was also a significant protective effect associated with the integrated community intervention program (**χ^2 = 5.83 for the interaction term, p = 0.016**). Compared to baseline, there was an estimated increase of 18.9% in the yielding percentage after all countermeasures were implemented (i.e., *M* = 38.8 % versus *M* = 19.8%). At generalized sites, the mean yielding percentage slightly decreased from 26.0% at baseline to 24.9% during the final treatment stage.
- At unsignalized intersections in Minneapolis, a significant (or borderline significant) treatment effect was also found during interim treatment stages 1 and 2.
- Relevant countermeasures that could be promising to improve the yielding performance included the combinations of bollards (i.e., interim treatment stage 2), and R1-6 signs (i.e., final treatment stage).
- Installations of lane conversion and bump-outs did not appear to affect the measured outcome at the intersection of "Lyndale & 21st" during interim treatment stage 3. However, it may take some time for the effect of these interventions to be reliably detected. Such a delayed effect could have also contributed to the greater increase observed in the yielding percentage at this site, in combination with the effect of bollards and pedestrian refuge islands implemented during the final treatment stage. Alternatively, these treatments may improve driver safety in other ways rather than crosswalk law compliance, i.e., for example potential reductions in vehicle speeds which were not measured in this study.

- Further input from the city of Minneapolis and MnDOT TAP members would be helpful to better interpret the shift in the direction of the yielding performance between treatment and generalization sites at unsignalized intersections, during interim treatment stage 1 in Minneapolis.

3.3.3 Evaluation of Program Performance at Signalized Intersections

3.3.3.1 Overview of Engineering Countermeasures at Signalized Intersections

The second examination of the primary analysis examined the treatments applied to the signalized intersections in both the cities of Minneapolis and Saint Paul. The overview of the types of signalized treatments and the schedule of deployment of the treatments are shown in Figure 3.5. An image of each treatment and the associated locations of the treatments are shown in Table 3.4.

SIGNALIZED INTERSECTION EVALUATION APPROACH

INITIAL DATA MANAGEMENT

The primary outcome of interest involved drivers' right-turning and left-turning yielding behaviors at signalized intersections. In the present study, large variations in the weekly yielding percentage were observed at both treatment and generalization signalized intersections due to the low number of observed conflicts between pedestrians and vehicles. For analysis purposes, yielding percentage was further categorized into five ordinal levels that indicated drivers' compliance with stopping for pedestrians at intersections. These levels included drivers' yielding: 1) less than 25% of the time; 2) greater than 25% and less than or equal to 50% of the time; 3) greater than 50% and less than or equal to 75% of the time; 4) greater than 75% and less than or equal to 90% of the time; and 5) greater than 90% of the time, during each data collection session. For example, the first category (i.e., Level 1) can also be interpreted as on average of less than 1 in 4 vehicles yielding to pedestrians at the intersection when accounting for all observed traffic turning right or left at this intersection across multiple data collection cycles. Level 1 was also treated as the low compliance level and was separately analyzed with the other extreme (i.e., Level 5 or the high compliance level).

Signalized Intersection Data Analysis Method

Descriptive statistics on the yielding percentage were provided for each intervention and generalization site at different treatment stages. Distributions of the compliance categories were also provided, separately, by intervention group and city. Consistent with the evaluations of unsignalized intersections, four research questions were addressed through analyzing drivers' performance on stopping for pedestrians at signalized intersections (Also see Section 3.2.2.3).

As with the unsignalized intersections, the questions for the signalized intersections included examinations of:

1) overall differences of outcome between the two cities over time,
2) effect of the feedback signs in each city,
3) treatment effect of the interim interventions during various treatment stages in each city,
4) treatment effect of the integrated community intervention program in each city.

For evaluating questions 1 and 2, the weekly yielding percentage was used (i.e., continuous outcome). For evaluations questions 3 and 4, the goal was to analyze changes in drivers' overall levels of compliance with stopping for pedestrians as well as their risk of having the two extreme compliance levels (i.e., levels 1 and 5 as indicated previously), across baseline and various treatment stages.

Signalized Intersection Statistical Analysis Method

The Generalized Estimating Equations (GEEs), applied with the independent correlation matrix, were utilized to account for the correlations of outcome data within repeated measures on the same intersection in the models. For analyzing drivers' compliance levels of stopping for pedestrians, relative risk ratios (RRRs) were calculated using a series of ordinal logistic regression models to compare the likelihoods of having a higher yielding compliance level during a specific post-treatment stage, to those at baseline. As supplemental analyses, log-binomial models were utilized to estimate risk ratios (RRs) and corresponding 95% for evaluating the binary outcomes of highest yielding compliance (i.e., equal to or greater than 90% of the time) and lowest yielding compliance (i.e., less than 25% of the time). Relevant effect measures were provided, separately, in each of the treatment and generalization groups, stratified by the city.

For the above-mentioned models, the result was significant if the 95% CIs of the measures of effects did not include the value of 1. Potential treatment effects were indicated by statistically significant Type III effects associated with the interaction terms of *Intervention group* (i.e., an intervention or generalization intersection) and *Time of intervention* (i.e., 0 = pre-treatment or 1 = post-treatment). Countermeasures may also be plausibly associated with performance improvement, if a significant and protective effect was present in the treatment group but was absent in the generalization group. In each multivariate model, the covariate variables were the same as the analyses of unsignalized intersections. All statistical analyses were performed using the SAS software version 9.4.

ENGINEERING COUNTERMEASURES AT SIGNALIZED INTERSECTIONS RESULTS

DIFFERENCES OF OUTCOME BETWEEN THE TWO CITIES AND OVER TIME

Overall, there was a significant main effect of City on the right-turning percentage (**χ^2 = 5.10, *p* = 0.024**), with the outcome being slightly greater in Saint Paul than in Minneapolis *(M* = 87.3%, *SD* = 26.3%, and *M* = 84.3%, *SD* = 31.9%, respectively). No significant temporal effect on the right-turning yielding percentage was found.

None of the main or interaction effects of city and time (i.e., in week) was statistically significant regarding the outcome of weekly left-turning yielding percentage. The average left-turning yielding percentage at signalized intersections was 75.7% (*SD* = 38.0%) in Saint Paul and 75.5% (*SD* = 38.3%) in Minneapolis. See Figure 3.6.

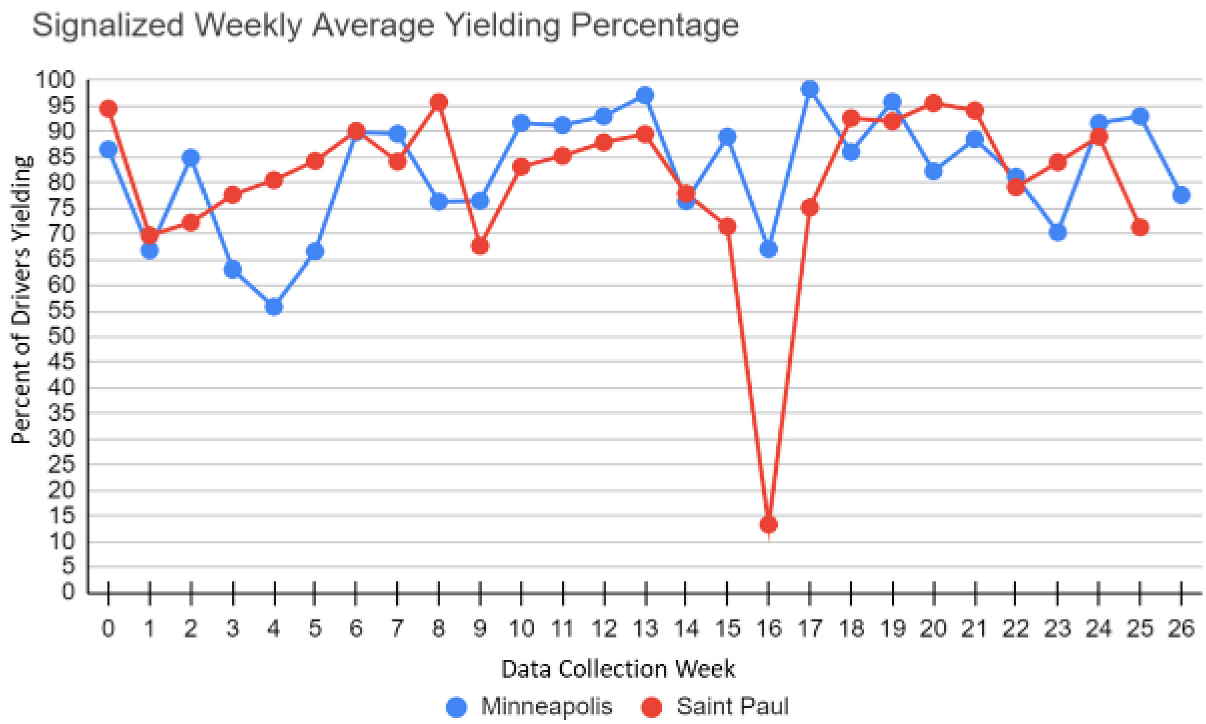


Figure 3.6 Overall average yielding percentage (right and left-turning combined) at signalized intersections

SIGNALIZED INTERSECTIONS IN SAINT PAUL

INFERENTIAL STATISTICAL ANALYSIS RESULTS FOR RIGHT-TURNING YIELDING BEHAVIORS

Effect of the Feedback Signs in Saint Paul: Among all signalized generalization intersections in Saint Paul, the average right-turning yielding percentage after the community feedback signs (*M* = 84.2%, *SD* = 29.7%) was not statistically different from that before their implementation, *(M* = 87.4%, *SD* = 30.1%), χ^2 = 1.04, *p* = 0.308.

Treatment Effect of the Interim Interventions during Stage 1: The interaction effect of the treatment group and time of treatment was not statistically significant for analyzing the overall yielding compliance levels (χ^2 = 3.04, *p* = 0.385). At treatment sites, the likelihood of drivers having a higher level of yielding compliance while turning right during the treatment stage 1 was 1.56 times that at baseline (RRR = 1.56, 95% CI = [0.68, 3.60], *p* = 0.293). At generalization sites, the risk of having a higher level of yielding compliance was 0.87 times less likely when comparing the post-treatment period to baseline (RRR = 0.87, 95% CI = [0.24, 3.19], p = 0.828).

Treatment Effect of the Integrated Community Intervention Program: The effect associated with the interaction term was not statistically significant after all the community intervention program was implemented (χ^2 = 4.04, p = 0.257). However, drivers were 0.77 times less likely to have a higher level of yielding compliance at treatment sites when comparing between the final treatment stage and baseline (RRR = 0.77, 95% CI = [0.40, 1.47], p = 0.423), whereas this risk was as low as 0.45 times *less likely* at generalization sites (**RRR = 0.45, 95% CI = [0.38. 0.53], *p* < 0.001**).

Highest and Lowest Levels of Yielding Compliance across Stages: During interim treatment stage 1, none of the results for analyzing the highest level of yielding compliance was statistically significant, at either treatment sites (RRR = 1.58, 95% CI = [0.75, 3.34], p = 0.231), or generalization sites (RRR = 0.90, 95% CI = [0.24, 3.42], p = 0.881). During the final treatment stage, drivers were significantly *less likely* to have the highest level of compliance (i.e., during 90% of the time and above) with stopping for pedestrians while turning right at generalization sites (**RRR = 0.48, 95% CI = [0.38, 0.59], *p* < 0.001**), whereas such a decrease was not significant in the presence of the community intervention program (RRR = 0.76, 95% CI = [0.38, 1.54], p = 0.451). Regarding the lowest level of yielding compliance, the models did not converge due to the small sample of events observed at the treatment sites.

Other covariates: No statistically significant associations were found.

INFERENTIAL STATISTICAL ANALYSIS RESULTS FOR LEFT-TURNING YIELDING BEHAVIORS

Effect of the Feedback Signs in Saint Paul: Among all signalized generalization intersections in Saint Paul, the average left-turning yielding percentage after the community feedback signs slightly increased compared to the pre-treatment period (M = 74.8%, SD = 41.2%, and M = 70.4%, SD = 41.7%, respectively). However, the result of pre-post comparison was not statistically significant, χ^2 = 0.48, p = 0.488.

Treatment Effect of the Interim Interventions during Stage 1: The interaction effect of the treatment group and time of treatment was not statistically significant for analyzing the overall left yielding compliance levels (χ^2 = 3.17, p = 0.366). At treatment sites, the likelihood of drivers having a higher level of yielding compliance while turning left during the treatment stage 1 was 1.30 times that at baseline (RR = 1.30, 95% CI = [0.26, 6.45], p = 0.748). At generalization sites, the risk of having a higher level of yielding compliance was 1.75 times less likely when comparing the post-treatment period to baseline (RR = 1.75, 95% CI = [0.63, 4.88], p = 0.286).

Treatment Effect of the Integrated Community Intervention Program: Similarly, the effect associated with the interaction term was not statistically significant after all the community intervention program was implemented (χ^2 = 4.28, p = 0.232). Drivers appeared to be more likely to have a higher level of left-turning yielding compliance at treatment sites (RR = 2.00, 95% CI = [0.60, 6.67], p = 0.259), and at generalization sites (RR = 1.33, 95% CI = [0.77, 2.31], p = 0.310). Yet neither of the effects was statistically significant.

Highest and Lowest Levels of Yielding Compliance across Stages: Compared to baseline, drivers in general were more likely to have the highest level of left-turning yielding compliance during both the interim treatment stage 1 and the final treatment stage. At the same time, their risk of having the lowest level of left-turning yielding compliance also decreased during different stages of the program implementation. This trend applies for both treatment sites and generalization sites, yet none of the results were statistically significant and thus were not reported here.

Other covariates: No statistically significant associations were found.

OBSERVED LEFT-TURNING YIELDING VIOLATION BEHAVIORS RELATING TO LEADING PROTECTED LEFT

Researchers noted that left-turning violations were observed at Ford Parkway & Cleveland Ave and at Snelling Ave & Selby Ave in situations relating to the signal's protected-permitted left-turn (PPLT) phasing. When left-turning drivers were not able to turn within the PPLT phase (i.e., they no longer had a green arrow to make the turn), they would attempt to quickly turn left during the start of the signal's permissive-only left-turn phasing (i.e., green ball) before oncoming traffic had entered the intersection. This maneuver is sometimes referred to as a "Pittsburgh left". The illegal maneuver is particularly dangerous because the pedestrian walk signal is activated at the same time as the green ball phase.

Researchers observed multiple instances at both study sites when pedestrians were able to enter the crosswalk before oncoming drivers entered the intersection (i.e., which would restrict left-turning movements). These sites may be more at risk for this scenario due to higher pedestrian volumes and greater likelihood that pedestrians are waiting at the corner for the signal to turn and immediately ready to enter the crosswalk. This scenario resulted in several observed close calls in which the violating left-turning driver made a fast maneuver to beat oncoming traffic but failed to recognize that a pedestrian had already entered the crosswalk. One observed close call involved a visibly pregnant pedestrian who was nearly struck at Ford Parkway & Cleveland Ave in such a scenario.

One solution may be to hold the pedestrian walk signal for one or two seconds to delay releasing pedestrians into the crosswalk until oncoming traffic can enter the intersection and serve as a blockade for pedestrians. This is a less than an ideal solution because it prioritizes vehicle throughput over pedestrian throughput but may be necessary to protect pedestrians from this known risk. A potential risk of such a solution is that pedestrians would become impatient and violate the signal; however, this may be an unlikely outcome since these locations have high traffic volumes, and few pedestrian violations were observed during the study. An alternative solution would involve larger changes to the traffic signal to provide a red indication for turning vehicles after the permissive-only left-turn phase until the LPI phase has ended.

Signalized Intersections in Minneapolis

MINNEAPOLIS SIGNALIZED INTERSECTIONS DESCRIPTIVE STATISTICS

For signalized intersections in Minneapolis, two treatment stages were generated based on the implementation schedule of interventions. The interim treatment stage 1 included week 11 to week 17 of data collection. In addition to the community feedback signs, several engineering countermeasures were also initiated in week 11. During this treatment stage, the observed countermeasures included bollards, Leading Pedestrian Interval (LPI), and hardened centerlines at two intersections of "Nicollet Ave & W 35th St" and "Chicago Ave & S 8th St". At the intersection of "Lyndale Ave N & 18th Ave", the implementation of lane conversion started at week 18, followed by the installation of hardened centerlines in week 21. Table 3.6 summarizes the right and left-turning yielding percentage at each signalized intersection in Minneapolis during different treatment stages.

Table 3.6 A summary table of the right and left-turning yielding percentage (n of data points in parentheses) at each signalized intersection in Minneapolis during different treatment stages

	Right-turning yielding			Left-turning yielding		
	Baseline Period	**Interim Treatment Stage 1**	**Final Treatment Stage**	**Baseline Period**	**Interim Treatment Stage 1**	**Final Treatment Stage**
Treatment Sites						
Chicago & S 8th	81.1% (11)	100% (2)	100% (13)	84.4% (8)	100% (2)	90.0% (5)
Nicollet & 35th	83.3% (6)	100% (2)	100% (4)	75.0% (4)	100% (3)	66.7% (3)
Lyndale & N 18th	66.7% (12)	83.3% (6)	80.8% (13)	80.0% (15)	75.0% (6)	80.0% (15)
Generalization Sites						
Dowling & Fremont	66.7% (3)	100% (8)	83.3% (7)	60.0% (5)	85.7% (7)	85.7% (7)
Franklin & Nicollet	80.1% (23)	84.9% (18)	82.2% (26)	90.4% (17)	58.5% (13)	78.3% (15)
Lowry & 2nd	88.9% (9)	100% (8)	100% (13)	90.0% (11)	100% (7)	75.0% (12)
Lowry & Lyndale	72.0% (22)	88.5% (13)	78.1% (16)	65.6% (15)	73.3% (10)	70.6% (17)
Nicollet & 38th	85.7% (14)	88.9% (9)	78.8% (11)	70.0% (10)	87.5% (4)	70.5% (13)

Figure 3.7 illustrates the distributions of right-turning yielding compliance levels at signalized intersections in Minneapolis, by treatment group. At treatment sites, the overall right-turning yielding performance appeared to be improved during interim treatment stage 1 and persisted until the final treatment stage. Similarly, the proportions of having the lowest level of yielding compliance also seemed to consistently decrease over time. However, at generalization sites, the improvement in performance may not be as great, particularly when comparing the final treatment stage to baseline. In addition to the limitations with the small data set in this sample, a ceiling effect in these yielding numbers may have influenced these results since there was less room for improvement (i.e., numbers near 100%) to detect change.

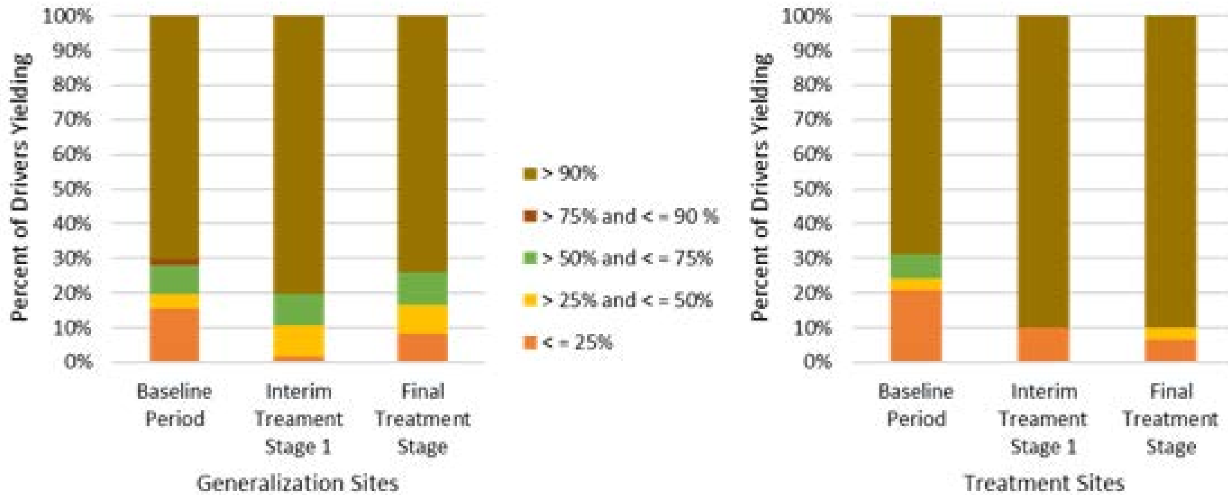


Figure 3.7 Distributions of right-turning yielding compliance levels at signalized generalization and treatment intersections in Minneapolis

Regarding left-turning yielding, the trend in the change of performance did not appear to differ substantially between treatment and generalization sites (see Figure 3.8). During interim treatment stage 1, a potential improvement in the left-turning yielding performance may be observed for both groups, compared to the distribution at baseline. However, this trend appeared to reverse toward the final treatment phase, particularly for the generalization sites.

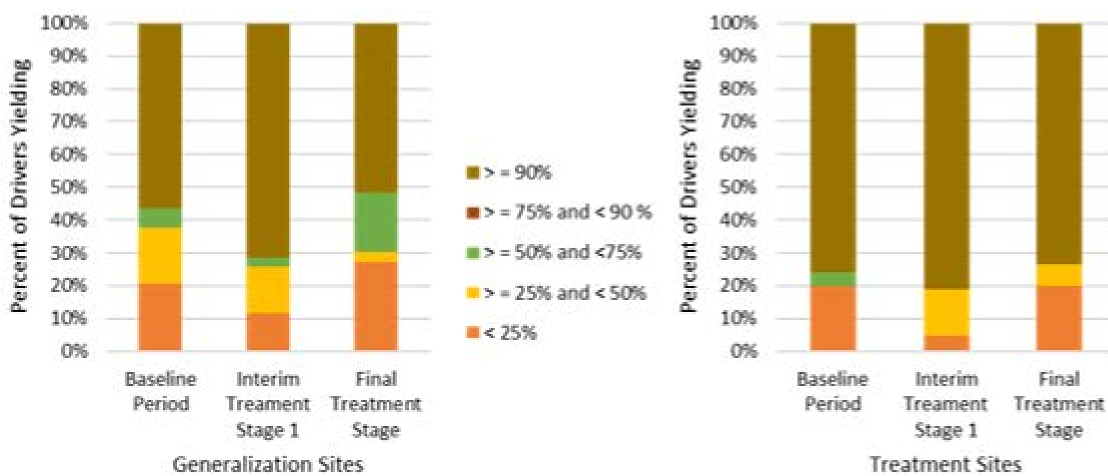


Figure 3.8 Distributions of left-turning yielding compliance levels at signalized generalization and treatment intersections in Minneapolis

INFERENTIAL STATISTICAL ANALYSIS RESULTS FOR RIGHT-TURNING YIELDING BEHAVIORS

Effect of the Feedback Signs in Minneapolis: Although not statistically significant, the result appeared to be important where a greater right-turning yielding percentage was found after the community feedback signs were implemented at week 11 and after (*M* = 86.9%, *SD* = 27.2%), compared to that before week 11 (*M* = 79.2%, *SD* = 36.9%), χ^2 = 2.95, *p* = 0.086.

Treatment Effect of the Interim Interventions during Stage 1: The effect associated with the interaction term during interim treatment stage 1 was not statistically significant (χ^2 = 7.34 for the interaction term, *p* = 0.062). At generalized intersections, the likelihood of having a higher level of right-turning yielding compliance during the post-treatment period was 1.83 times that of the baseline period (**RRR = 1.83, 95% CI = [1.04, 3.21], *p* = 0.036**). At treatment sites, a much greater effect was found associated with the interventions, where the relative risk ratio of having a higher level of right-turning yielding compliance increased to 5.20 times greater (**RRR = 5.20, 95% CI = [1.97, 13.69], *p* < 0.001**).

Treatment Effect of the Integrated Community Intervention Program: The effect associated with interventions during the final treatment stage was not statistically significant, either (χ^2 = 6.04 for the interaction term, *p* = 0.110). While the community intervention program significantly increased the likelihood of having a higher level of right-turning yielding compliance at treatment sites (**RRR = 5.10, 95% CI = [1.12, 23.10], *p* = 0.035**), there was no statistically significant change of risk at generalization sites (RRR = 1.26, 95% CI = [0.87, 1.83], *p* = 0.215).

Highest and Lowest Levels of Yielding Compliance across Stages: Compared to baseline, drivers were more likely to have the highest level of right-turning yielding compliance at both treatment and generalization sites. In general, a greater protective effect was observed at treatment sites, compared to generalization sites across stages. Specifically, during interim treatment stage 1, a statistically significant effect was found at treatment sites (**RR = 4.66, 95% CI = [1.57, 13.84], *p* = 0.006**), but not at generalization sites (RR = 1.71, 95% CI = [0.98, 2.98], *p* = 0.057, borderline). Neither of the effects was significant during the final treatment stage.

Drivers' risk of having the lowest level of right-turning yielding compliance also decreased during different stages of the program implementation at both sites. During the final treatment stage, the risk of drivers' stopping for pedestrians during less than or equal to 25% of time while turning right (i.e., lowest level of right-turning yielding compliance) was 0.24 times of that at baseline (**RR = 0.24, 95% CI = [0.11, 0.53], *p* < 0.001**). Relevant risk reduction was not statistically significant at generalization sites (RR = 0.54, 95% CI = [0.28, 1.05], *p* = 0.068).

Other covariates: The likelihood of drivers having a higher level of right-turning yielding compliance during the final stage tended to increase associated with one unit increase in the length of the major road crosswalks (**χ^2 = 4.74, *p* = 0.030**).

INFERENTIAL STATISTICAL ANALYSIS RESULTS FOR LEFT-TURNING YIELDING BEHAVIORS

Effect of the Feedback Signs in Minneapolis: Among all signalized generalization intersections in Minneapolis, the left-turning yielding percentage during the post-treatment period of the community feedback signs (*M* = 75.6%, *SD* = 37.6%) was not statistically different from that during the pre-treatment period (*M* = 69.1%, *SD* = 40.8%), (χ^2 = 2.16, *p* = 0.142).

Treatment Effect of the Interim Interventions during Stage 1: The effect associated with the interaction term during interim treatment stage 1 was not statistically significant (χ^2 = 4.33 for the interaction term, *p* = 0.228). Compared to baseline, drivers were more likely to have a higher level of left-turning yielding compliance at both generalization and treatment sites, however, neither of the increase was statistically significant (RRR = 1.56, 95% CI = [0.94, 2.61], *p* = 0.088 for generalization sites, and RRR = 1.46, 95% CI = [0.33, 6.50], *p* = 0.616 for treatment sites, respectively).

Treatment Effect of the Integrated Community Intervention Program: The effect associated with interventions during the final treatment stage was not statistically significant (χ^2 = 2.39 for the interaction term, *p* = 0.495). When comparing between the final treatment stage and baseline, the likelihood of drivers having a higher level of left-turning yielding compliance increased at generalization sites (RRR = 1.23, 95% CI = [0.76, 1.99], *p* = 0.395), but decreased at treatment sites (RRR = 0.88, 95% CI = [0.67, 1.15], *p* = 0.342).

Highest and Lowest Levels of Yielding Compliance across Stages: During interim treatment stage 1, the likelihood of drivers having the highest level of left-turning yielding compliance was slightly greater at treatment sites (RRR = 1.08, 95% CI = [0.27, 6.55], *p* = 0.725), but significantly smaller at generalization sites (**RR = 0.48, 95% CI = [1.01, 2.60], *p* = 0.049**). During the final treatment stage, drivers were less likely to have the highest level of left-turning yielding compliance at treatment sites (RR = 0.84, 95% CI = [0.60, 1.17], *p* = 0.297), but not at generalization sites (RR = 1.15, 95% CI = [0.72, 1.85], *p* = 0.556).

At both treatment and generalization sites, drivers were less likely to have the lowest level of left-turning yielding compliance, regardless of the treatment stages. None of the results was statistically significant, when compared to the risk at baseline.

Other covariates: As with one unit increase in the length of the major road crosswalks, the likelihood of drivers having a higher level of left-turning yielding compliance also significantly increased during the final stage (**χ^2 = 4.29, *p* = 0.038**).

Summary of Results at Signalized Intersections

The results of program evaluations at signalized intersections in the present project are summarized below:

- Overall, left-turning yielding behaviors did not appear to differ between the two cities.
- There was a small effect of right-turning yielding being more frequent in Saint Paul relative to Minneapolis.
- Like unsignalized intersections, the feedback signs were less effective on their own in promoting drivers stopping for pedestrians at untreated signalized intersections. However, a slight increase in the yielding percentage was observed during the post-treatment period for most measured outcomes in each city.
- In both cities, the intervention program demonstrated some potential in promoting right-turning yielding performance but was less effective for left-turning yielding performance.

Specific to signalized intersections in Saint Paul:

- The engineering treatment program at treatment sites appeared to have helped to counteract the general decline in drivers' stopping for pedestrians while turning right (RRR = 0.77, 95% CI = [0.40, 1.47], $p = 0.423$), which could have been worse during the study period without the treatment (i.e., there was a significant decrease at generalization sites, **RRR = 0.45, 95% CI = [0.38. 0.53], $p < 0.001$**).
- The preventive effect was not observed until the final treatment stage, with the combinations of hardened centerlines and painted stop bars being implemented at most treatment sites. Suggesting that the "Stop for Pedestrians" signs were not as effective in mitigating these behavioral trends and traffic calming treatments, such as the hardened centerlines, should be further investigated in the future.
- Similarly, drivers were significantly less likely to have the highest level of right-turning yielding compliance (i.e., stopping for pedestrians during 90% of the time and above) at generalized sites during the final treatment stage. However, this decline in high yielding compliance was not observed at treatment sites.

Specific to signalized intersections in Minneapolis:

- In Minneapolis, compared to baseline, drivers in general had a greater likelihood of highly complying with stopping for pedestrians while turning right, during both interim treatment stage 1 (i.e., bollards, LPI, and hardened centerlines) and the final treatment stage (i.e., lane conversion and hardened centerlines).
- The right-turning yielding high compliance improvement was much greater at treatment sites than at generalization sites. Specifically, a statistically significant effect was associated with the engineering intervention program at treatment sites (**RRR = 5.10, 95% CI = [1.12, 23.10], $p = 0.035$**), but was not found at generalization sites (RRR = 1.26, 95% CI = [0.87, 1.83], $p = 0.215$).
- Drivers' risk of having the lowest level of right-turning yielding compliance (i.e., stopping for pedestrians during 25% of the time and less) was also significantly reduced at treatment sites (**RR = 0.24, 95% CI = [0.11, 0.53], $p < 0.001$**). The risk reduction was not statistically significant at generalization sites (RR = 0.54, 95% CI = [0.28, 1.05], $p = 0.068$).

3.4 EVALUATION OF THE PEDESTRIAN SAFETY PERCEPTION CHANGES

3.4.1 Evaluation of the Pedestrian Safety Perception Changes

3.4.1.1 Survey Purpose

Two online survey questionnaires were administered to the residents from both Saint Paul and Minneapolis before and after the implementation of the community intervention program within each city. This evaluation aimed to measure any perceived differences in the pedestrian safety culture between Saint Paul and Minneapolis, as well as to examine how these community-based perceptions could have been changed over time following the intervention program.

3.4.1.2 Recruitment Methods

Each survey was disseminated through multiple avenues to ensure accessibility to residents across a wide range of neighborhoods in the cities of Saint Paul and Minneapolis. The recruitment methods included posting announcements on social media platforms, such as Twitter, Facebook, and others. Additionally, emails containing the survey information and a secured link to the survey were sent to residents through the University of Minnesota's HumanFIRST Lab, the Minnesota Safety Council, the City of Saint Paul, the City of Minneapolis, and MnDOT.

Data collection periods involved two phases: Phase I, which ran from October 30, 2020 to January 15, 2021 (i.e., pre-intervention), and Phase II, which ran from November 8, 2021 to January 13, 2022 (i.e., post-intervention). Survey responses were collected through Qualtrics online survey platform. No personal identifying information was obtained. Potential participants were provided with a brief description of the purpose of the survey and were notified that their response was voluntary. Informed consent was not obtained because the survey was determined to be "not human-subjects research" by the University of Minnesota Institutional Review Board (IRB).

SURVEY PARTICIPANTS

Phase I survey involved N = 535 participants, including 211 (39.4%) who reported living in Saint Paul and 324 (60.6%) who reported living in Minneapolis. Phase II survey involved N = 848 participants, including 273 (32.2%) reported being Saint Paul residents and 575 (67.8%) reported being Minneapolis residents.

Participants were also asked to report which neighborhood they lived in. All 17 of Saint Paul neighborhoods were identified among survey respondents. In the Phase I survey, the top three neighborhoods that accounted for the greatest proportions of all sampled Saint Paul residents were Hamline Midway (n = 31, 14.7%), Como Park (n = 25, 11.8%), and North End (n = 23, 10.9%). In the Phase II survey, these top three neighborhoods were Highland Park (n = 41, 15.0%), Macalester-Groveland (n = 38, 13.9%), and Hamline Midway (n = 23, 8.4%).

Given the drastic differences in the number of official neighborhoods between the cities of Saint Paul and Minneapolis, i.e., 17 and 81 respectively, there was a much broader reporting of neighborhoods among Minneapolis participants. Participants reported living in 51 and 63 Minneapolis neighborhoods for Phase I and Phase II surveys, respectively. Downtown East/West (n = 35, 10.8%) and Standish-Ericsson (n = 25, 7.7%) ranked as the top two neighborhoods with the largest proportions of participating residents. In the Phase II survey, about 16.2% of participating Minneapolis residents reported living in the Longfellow (n = 51, 8.9%) and Kingfield (n = 42, 7.3%) neighborhoods.

Table 3.1 summarizes participants' demographic information for both survey phases. Nearly all participants were fully licensed drivers (i.e., 93.4% and 96.2%, respectively), with an average number of years licensed ranging from 29.5 to 34.2 years. There was a balanced distribution of age ranges across the two survey phases. One exception was that in the Phase II survey, 29.7% of the Saint Paul residents reported being 35-44 years old, whereas this age range accounted for 18.1% of the reporting

Minneapolis residents. Overall, approximately two-thirds of the respondents identified themselves to be female. Among those who reported living in Minneapolis, there was a significant difference in the gender distributions associated with the study phases (χ^2 = 14.36, p = 0.003, also see

Table 3.7). Nearly 80% of participants selected the city where they lived to be the city in which they would also drive the most. The proportion of those who reported being a non-driver (i.e., "I do not drive") was slightly higher among Minneapolis residents in the Phase II survey than other resident groups. Across both surveys, less than 10% of participants reported working in a transportation-related field or had ever taken a similar survey (e.g., responding to the Phase II survey after having taken the Phase I Survey, or having previously taken the survey from the 2018 Saint Paul study).

Table 3.7 Participants' demographic information

	Phase I Survey (Before, N = 542)				Phase II Survey (After, N = 848)			
	Saint Paul Residents (n = 211)		Minneapolis Residents (n = 324)		Saint Paul Residents (n = 273)		Minneapolis Residents (n = 575)	
	n	%	n	%	n	%	n	%
Licensed driver								
Yes, full license	203	*96.2*	309	*95.4*	260	*95.2*	537	*93.4*
Yes, learner's permit	2	*0.9*	2	*0.6*	1	*0.4*	5	*0.9*
No	6	*2.8*	13	*4*	12	*4.4*	33	*5.7*
Number of years licensed	34.2	*15.5*	33.8	*15.8*	29.5	*14.6*	32.9	*16.2*
Age range								
18-24	5	*2.4*	9	*2.8*	4	*1.5*	20	*3.5*
25-34	25	*11.8*	45	*13.9*	37	*13.6*	89	*15.5*
35-44	42	*19.9*	47	*14.5*	81	*29.7*	104	*18.1*
45-54	36	*17.1*	56	*17.3*	43	*15.8*	82	*14.3*
55-64	39	*18.5*	58	*17.9*	43	*15.8*	90	*15.7*
65-74	42	*19.9*	56	*17.3*	22	*8.1*	95	*16.5*
75 and above	4	*1.9*	13	*4*	5	*1.8*	32	*5.6*
I'd rather not say	5	*2.4*	6	*1.9*	4	*1.5*	8	*1.4*
Missing	13	*6.2*	34	*10.5*	34	*12.5*	55	*9.6*
Gender								
Female	137	*64.9*	182	*56.2*	133	*48.7*	300	*52.2*
Male	49	*23.2*	92	*28.4*	97	*35.5*	175	*30.4*
Non-binary or Other	5	*2.4*	7	*2.2*	4	*1.5*	26	*4.5*
Missing	20	*9.5*	43	*13.3*	39	*14.3*	74	*12.9*
Which city do you drive in the most?								
Saint Paul	179	*84.8*	31	*9.6*	228	*83.5*	454	*79.0*
Minneapolis	19	*9*	261	*80.6*	19	*7.0*	33	*5.7*
I do not drive	9	*4.3*	25	*7.7*	19	*7.0*	74	*12.9*
Missing	4	*1.9*	7	*2.2*	7	*2.6*	14	*2.4*
Work in transportation-related field								
Yes	13	*6.2*	30	*9.3*	25	*9.2*	47	*8.2*
No	185	*87.7*	260	*80.2*	214	*78.4*	469	*81.6*
Missing	13	*6.2*	34	*10.5*	34	*12.5*	59	*10.3*
Reported to take a similar survey								
Yes	12	*5.7*	6	*1.9*	18	*6.6*	30	*5.2*

No	158	*74.9*	262	*80.9*	195	*71.4*	443	*77.0*
Unsure	28	*13.3*	22	*6.8*	26	*9.5*	45	*7.8*
Missing	13	*6.2*	34	*10.5*	34	*12.5*	57	*9.9*

3.4.2 Survey Responses

The following session comprises data analysis for four topic areas:

1. Participants' self-reported frequencies of driving and crossing the crosswalk in both cities
2. Perceived risks for different types of crosswalks in both cities
3. Knowledge of the Minnesota crosswalk law
4. Awareness of the community intervention program, including the blue feedback signs.

3.4.2.1 Data Analysis Methods

The primary exposure of interest was the Study Time, with 0 indicating Phase I survey (i.e., pre-intervention period) and 1 indicating Phase II survey (i.e., post-intervention period). Because participants were provided with the same set of questions for assessing their driving/crossing frequencies and perceived risk levels in Saint Paul and Minneapolis separately, an additional variable of City (being rated) was also included as a predictor in the models to examine whether any significant difference existed between the two cities. For the first two topic areas, an overall evaluation was conducted to analyze the effects of Study Time and City, as well as their interaction effect. The last two topic areas also examined how participants perceptions may differ by which city participants lived in and by Study time. Linear regression models were used to estimate the mean difference of the response scores across the levels of predictors. Logistic regression models were used to estimate the odds ratio of having a correct response for certain measures.

Several covariate variables were adjusted for in the statistical models, including drivers' age range, gender, and their driver license status. Due to limited sample size for these participants, participants aged 75 and above were further collapsed with those aged 65-74 into one aggregated age range of 65 and above. Gender was defined as a categorical variable with three levels of male, female and Non-binary/Others. In the present analyses, the variable of driver license status was considered as a binary variable (i.e., 0 = either having no driver license or a learner's permit; 1 = having a full driver license).

Relevant outcome data were re-coded based on a 4-point or 5-point Likert-score scaling system. For example, the frequency measure was defined as 1-Yearly; 2-Monthly; 3-Weekly; and 4-Daily. Ratings on the perceived risks for different types of crosswalks were coded as 1-Very unsafe; 2-Somewhat unsafe; 3-Neutral; 4-Somewhat safe; and 5-Very safe.

3.4.2.2 Frequencies of Driving and Crossing the Crosswalk

OVERALL EVALUATION

Q1. HOW OFTEN DO YOU DRIVE IN [CITY NAME], MN?

There was a main effect of City (***F* = 55.81, *p* < .001**). In general, participants reported to drive significantly more frequently in Minneapolis than in Saint Paul (**Mean difference = 0.31, 95% CI = [0.23, 0.39]**). The interaction effect of City and Study time was also significant (***F* = 21.90, *p* < .001**). Participants' self-reported driving frequency was significantly higher in Minneapolis during the post-treatment period, compared to the pre-intervention period (**Mean difference = 0.25, 95% CI = [0.10, 0.40]**). The average difference of self-reported driving frequency was not significant in Saint Paul (Also see Table 3.8).

Table 3.8 Participants' self-reported driving frequency in Saint Paul and Minneapolis

	In Saint Paul		**In Minneapolis**	
	N	*Mean (SD)*	*N*	*Mean (SD)*
Phase I	477	2.64 (0.97)	485	2.76 (0.89)
Phase II	726	2.52 (1.05)	724	3.02 (0.86)
Overall	1203	2.57 (1.02)	1209	2.91 (0.88)

Q2: HOW OFTEN DO YOU CROSS THE CROSSWALKS IN [CITY NAME], MN?

In line with the driving frequency results, participants overall were also found to cross the crosswalks more frequently in Minneapolis than in Saint Paul (***F* = 182.88, *p* < .001, Mean difference = 0.65, 95% CI = [0.55, 0.74]**). There was a significant interaction effect between City and Study time (***F* = 15.72, *p* < .001**). When comparing between the post- and pre- intervention periods, the self-reported frequency of crossing the crosswalk slightly increased in Minneapolis (**Mean difference = 0.19, 95% CI = [0.02, 0.99]**), whereas a reversed direction was found in Saint Paul (**Mean difference = -0.19, 95% CI = [-0.36, -0.01]**). Participants reported to have a significantly higher frequency of crossing the crosswalk as their age range increased (***F* = 6.28, *p* = 0.012**), see Table 3.9.

Table 3.9 Participants' self-reported frequency of crossing the crosswalk in Saint Paul and Minneapolis

	In Saint Paul		**In Minneapolis**	
	N	*Mean (SD)*	*N*	*Mean (SD)*
Phase I	503	2.38 (1.17)	509	2.83 (1.16)
Phase II	805	2.21 (1.15)	805	3.04 (1.07)
Overall	1308	2.27 (1.16)	1314	2.96 (1.11)

Stratified Analyses Among Residents and Non-Residents

Q1. HOW OFTEN DO YOU DRIVE IN [CITY NAME], MN?

Driving frequency ratings among residents only. When individually evaluating the city where participants lived, the main effect of Study was significant (***F* = 15.53, *p* < .001**). In general, residents reported to drive more frequently in 2021 compared to 2020 (Mean difference = 0.18, 95% CI = [0.09, 0.27]; *M* = 3.38, *SD* = 0.70 versus *M* = 3.19, *SD* = 0.75). There was also a main effect of City being rated (***F* = 30.69, *p***

< .001). A higher driving frequency was identified in Saint Paul than in Minneapolis (**Mean difference = 0.25, 95% CI = [0.16, 0.34]**; *M* = 3.45, *SD* = 0.66 versus *M* = 3.23, *SD* = 0.75). Not surprisingly, drivers who held a full driver's license drove significantly more frequently than those without a full driver's license (**Mean difference = 1.06, 95% CI = [0.60, 1.52]**; *M* = 3.32, *SD* = 0.72 versus *M* = 2.30, *SD* = 0.95). Participants who identified themselves to be non-binary or other gender identity (*M* = 2.92, *SD* = 1.00) reported to drive less frequently than those who identified themselves to be either a male (*M* = 3.30, *SD* = 0.77) or female (*M* = 3.32, *SD* = 0.68).

Driving frequency ratings among non-residents (i.e., from the other city) only. The main effect of City was found to be significant, only (***F* = 31.64, *p* < .001**). Non-residents reported to drive more frequently in Minneapolis than in Saint Paul (**Mean difference = 0.29, 95% CI = [0.19, 0.40]**; *M* = 2.36, *SD* = 0.83, and *M* = 2.06, *SD* = 0.82, respectively).

Q2: *HOW OFTEN DO YOU CROSS THE CROSSWALKS IN [CITY NAME], MN?*

Crossing frequency ratings among residents only. Residents' self-reported frequency of crossing the crosswalk in their own city decreased as their age increased (*F* = 5.28, *p* = 0.022). There was no other significant main effect or interaction effect.

Crossing frequency ratings among non-residents (i.e., from the other city) only. The main effect of City was significant (***F* = 36.82, *p* < .001**). Non-residents (i.e., participants from the other city) reported to cross the crosswalk more frequently in Minneapolis than in Saint Paul (**Mean difference = 0.31, 95% CI = [0.21, 0.41]**; *M* = 1.98, *SD* = 0.89, and *M* = 1.64, *SD* = 0.79, respectively). Female participants (*M* = 1.71, *SD* = 0.80) crossed the crosswalks less frequently than those who identified themselves to be non-binary or other gender identity (*M* = 2.12, *SD* = 1.10), but were not statistically significantly different from the male participants (*M* = 1.82, *SD* = 0.87). Similarly, increased age was also associated with a lower self-reported frequency of crossing the crosswalk in the other city (***F* = 5.15, *p* = 0.023**).

3.4.2.3 Perceived Risks of Different Types of Crosswalks

Overall Evaluation

Q3: *HOW SAFE, IN GENERAL, DO YOU FEEL CROSSING AN UNMARKED CROSSWALK WITH NO TRAFFIC SIGNAL IN [CITY NAME], MN?*

There was a main effect of City (*F* = 3.90, *p* = 0.048). Overall, participants perceived crossing an unmarked crosswalk with no traffic signal to be slightly safer in Saint Paul than in Minneapolis (Mean difference = 0.10, 95% CI = [0.001, 0.20]; See

Table 3.10 for the overall Means and standard deviations). Also, as participants' age range increased, their ratings on the safety levels of these crosswalks slightly increased as well (***F* = 27.05, *p* < .001**).

Table 3.10 Participants' perceived risk levels for an unmarked crosswalk, with no traffic signal

	In Saint Paul		In Minneapolis	
	N	*Mean (SD)*	*N*	*Mean (SD)*
Phase I	501	2.73 (1.20)	507	2.63 (1.21)
Phase II	792	2.65 (1.15)	804	2.57 (1.20)
Overall	1293	2.68 (1.17)	1311	2.59 (1.21)

Q4. HOW SAFE, IN GENERAL, DO YOU FEEL CROSSING A MARKED CROSSWALK WITH NO TRAFFIC SIGNAL IN [CITY NAME], MN?

No statistically significant difference in the ratings was found across the levels of Study time or City. Female participants felt less safe to cross a marked crosswalk with no traffic signal than those who identified themselves to be non-binary or other gender identity (Mean difference = -0.12, 95% CI = [-0.24, -0.002]; M = 2.90, SD = 1.15, and M = 3.04, SD = 1.19, respectively). The difference between male and female participants was not statistically significant (M = 2.99, SD = 1.16 for males). Similarly, an increased age range was associated with a higher score for perceived safety in crossing marked crosswalks with no traffic signal (F = 19.89, p < .001), see Table 3.11.

Table 3.11 Participants' perceived risk levels for a marked crosswalk, with no traffic signal

	In Saint Paul		In Minneapolis	
	N	*Mean (SD)*	*N*	*Mean (SD)*
Phase I	498	3.00 (1.17)	502	2.90 (1.17)
Phase II	789	2.94 (1.12)	801	2.91 (1.17)
Overall	1287	2.96 (1.14)	1303	2.90 (1.17)

Q5. HOW SAFE, IN GENERAL, DO YOU FEEL CROSSING A MARKED CROSSWALK WITH A TRAFFIC SIGNAL IN [CITY NAME], MN?

Overall, participants who had a full driver's license perceived crossing a marked crosswalk with a traffic signal to be significantly safer than those who did not have a full driver's license (**Mean difference = 0.31, 95% CI = [0.11, 0.52]**; M = 2.94, SD = 1.16, and M = 2.74, SD = 1.08, respectively), see Table 3.12. There was no other significant main effect or interaction effect.

Table 3.12 Participants' perceived risk levels for a marked crosswalk, with a traffic signal

	In Saint Paul		In Minneapolis	
	N	*Mean (SD)*	*N*	*Mean (SD)*
Phase I	498	3.67 (1.08)	503	3.62 (1.09)
Phase II	785	3.63 (1.04)	798	3.66 (1.08)
Overall	1283	3.65 (1.05)	1301	3.64 (1.08)

3.4.2.4 Knowledge of the Minnesota Crosswalk Law

Respondents were provided with a few questions to survey their knowledge regarding the Minnesota Crosswalk Law (See 2021 Minnesota Statutes, Transportation, Chapter 169, Section 169.21 Pedestrian, Accessed online by https://www.revisor.mn.gov/statutes/cite/169.21).

In the following section, logistic regressions were used to model the odds of a correct response relevant to each survey question (i.e., the number of correct responses over the number of incorrect responses). For analysis purposes, the response of "Unsure" was treated as an incorrect response in the present study.

Q6: *DO YOU KNOW WHAT MINNESOTA LAW REQUIRES DRIVERS TO DO WHEN THEY APPROACH A PEDESTRIAN IN A CROSSWALK?*

Overall, 89.6% respondents reported that they were aware of the Minnesota law's requirements for drivers (see Table 3.13). There was no significant main effect identified by the study phase or by which city the participant lived in. When averaging across the two survey phases, 93.3% of Saint Paul residents and 87.6% of Minneapolis residents provided correct answers to this question.

Driver's license status and age range were identified to be significant influencing factors for respondents' knowledge of the Minnesota law's requirements for drivers. Specifically, the odds of a correct response among those who did not have a full driver's license was 0.4 times that of those who had a full driver's license (**Odds ratio = 0.40, 95% CI = [0.20, 0.79]**). The percent of correct answers was 90.3% among fully licensed drivers, compared to 76.6% among those non-drivers or those who had a learner's permit. As respondents' age range increased, the odds of having a correct response increased as well (**$\chi 2 = 15.22$, $p < .001$**).

Table 3.13 Knowledge of the Minnesota Crosswalk Law's requirements for drivers

	Answer		
	Yes	**No**	**Unsure**
Phase I (N=503)	92.3% (464)	2.8% (14)	5.0% (25)
Phase II (N=798)	88.0% (702)	3.0% (24)	9.0% (72)
Overall (Total N=1301)	89.6% (1166)	2.9% (38)	7.5% (97)

Q7: *IS THERE A DIFFERENCE IN WHAT DRIVERS MUST DO IF THE PEDESTRIAN IS CROSSING AT AN INTERSECTION BUT THERE IS NO PAINTED CROSSWALK?*

Participants were also asked to identify whether drivers should behave differently towards the pedestrian when the intersection was unmarked. Overall, about two thirds of the respondents demonstrated accurate knowledge of the law that there was no difference for what drivers must do if a pedestrian is at an intersection with no painted crosswalk (i.e., 72.3% of "No" responses, see

Table 3.14). The main effect of the study time was not significant ($\chi 2 = 1.20$, $p = 0.273$).

There was a significant main effect of the city where the participant lived in (**χ2 = 11.49, *p* < 0.001**). The odds ratio of having a correct answer was 1.91 when comparing Saint Paul residents to Minneapolis residents (**Odds ratio = 1.91, 95% CI = [1.31, 2.78]**; Percent of correct answers: 81.3% versus 67.3%, respectively). Respondents had higher odds of reporting a correct answer if they were a fully licensed driver (**χ2 = 8.40, *p* = 0.004**), or at a higher age range (**χ2 = 12.35, *p* < 0.001**).

Table 3.14 Difference of drivers' behavior at an intersection with no painted crosswalk

	Answer		
	Yes	**No**	**Unsure**
Phase I (N=500)	7.2% (36)	76.8% (384)	16.0% (80)
Phase II (N=790)	7.1% (56)	69.4% (548)	23.5% (186)
Overall (Total N=1290)	7.1% (92)	72.3% (932)	20.6% (266)

Q8: DO YOU KNOW WHAT MINNESOTA LAW REQUIRES PEDESTRIANS TO DO WHEN THEY CROSS THE ROAD IN A CROSSWALK?

Fewer participants reported to be aware of the Minnesota law's requirements for pedestrians as compared to the laws' requirements for drivers. As shown in Table 3.15, about 49.5% of the participants responded "Yes" whereas nearly 30.8% of them stated that they were "Unsure" about what Minnesota law requires pedestrians to do when they cross the road in a crosswalk.

The difference between Phase 1 and Phase 2 surveys was not statistically significant (χ2 = 0.11, *p* = 0.740). Age range was positively associated with an increased odds of reporting correct answers (**χ2 = 13.84, *p* < 0.001**). No other significant main effect or interaction effect was found.

Table 3.15 Knowledge of law's requirements for pedestrians

	Answer		
	Yes	**No**	**Unsure**
Phase I (N=497)	51.7% (257)	17.9% (89)	30.4% (151)
Phase II (N=783)	48.0% (376)	21.0% (164)	31.0% (243)
Overall (Total N=1280)	49.5% (633)	19.8% (253)	30.8% (394)

Q9: HOW STRICTLY DO YOU THINK THE POLICE ENFORCE THE MINNESOTA LAW REQUIRING DRIVERS TO STOP FOR PEDESTRIANS IN A CROSSWALK?

Overall, 75.3% of the respondents perceived the Minnesota police enforcement on the crosswalk law to be either "Not at all" (39.5%) or "Rarely" (35.8%), see Table 3.16. Compared to the Phase I survey, the perception that the law is enforced "Not at all" was more prevalent in the Phase II survey (42.6% in Phase II versus 34.7% in Phase I).

Responses were re-coded based on a 5-point Likert scale, with "Not at all" being equivalent to 0 and "Very strictly" being equivalent to 4. The main effect of Study time was borderline significant (*F* = 3.82, *p* = 0.051), where a slightly lower score was found during the post-intervention period compared to the pre-intervention period (*M* = 0.86, *SD* = 0.92, and *M* = 1.02, *SD* = 0.96, respectively). The city of residence also significantly affected respondents' perception on the involvement of law enforcement ($F = 17.38$, $p < .001$). Saint Paul residents perceived the police enforce the Minnesota crosswalk law slightly more strictly than Minneapolis residents (**Mean difference = 0.24, 95% CI = [0.13, 0.35]**; *M* = 1.07, *SD* = 0.96, and *M* = 0.84, *SD* = 0.92, respectively). As respondents' age range increased, their score for the perception of the stringency levels of the law enforcement also increased (**$F = 13.61$, $p < 0.001$**).

Table 3.16 Assessments on the stringency of law enforcement for Minnesota crosswalk law

	Phase I (N = 493)	**Phase II** (N = 777)	**Overall** (Total N=1270)
Not at all	34.7% (171)	42.6% (331)	39.5% (502)
Rarely	37.1% (183)	35.0% (272)	35.8% (455)
Not very strictly	21.5% (106)	16.9% (131)	18.7% (237)
Somewhat strictly	4.9% (24)	4.5% (35)	4.7% (59)
Very strictly	1.8% (9)	1.0% (8)	1.3% (17)

Q10: IN THE PAST MONTH, HAVE YOU SEEN ANY SPECIAL POLICE ENFORCEMENT AT CROSSWALKS NEAR WHERE YOU LIVE OR TYPICALLY DRIVE?

Most participants did not recall having seen any special police enforcement at crosswalks near where they lived or typically drove (95.7%). As shown in Table 3.11, little difference was observed between Phase I and Phase II surveys. The city of residency significantly affected the odds of reporting a "Yes" or "Maybe" answer to this question (**$\chi 2 = 4.63$, $p = 0.031$**). Compared to Minneapolis residents, Saint Paul residents had 1.23 times higher odds of recalling seeing any special police enforcement at crosswalks in the neighborhood (**Odds ratio = 2.24, 95% CI = [1.07, 4.67]**; Percent of "Yes" or "Maybe" answers: 97.0% for Saint Paul residents versus 93.5% for Minneapolis residents). Males were more likely to report having seen any special police enforcement at crosswalks than females (**$\chi 2 = 10.06$, $p = 0.007$ for the effect of gender**).

Table 3.17 Knowledge of any special police enforcement at crosswalks in the neighborhood

	Yes	**No**	**Maybe**
Phase I (N=493)	2.6% (13)	95.5% (471)	1.8% (9)
Phase II (N=776)	1.4% (11)	95.9% (744)	2.7% (21)
Overall (Total N=1269)	1.9% (24)	95.7% (1215)	2.4% (30)

3.4.2.5 Feedback Sign Knowledge

Q11: IN THE PAST MONTH, HAVE YOU SEEN OR HEARD ANY PUBLICITY ABOUT DRIVERS STOPPING FOR PEDESTRIANS IN CROSSWALKS?

Overall, approximately 87.4% of respondents did not recall having seen or heard any publicity about drivers stopping for pedestrians in crosswalks in the past month. However, a notable improvement in respondents' awareness of the publicity was observed after the intervention program (16.5% in Phase II versus 6.5% in Phase I, see Table 3.18). Such an effect of the Study time on the odds of responding "Yes" was significant (**$\chi 2 = 12.74$, $p < 0.001$**).

Additionally, there was also a significant main effect of the city where the participant lived in (**$\chi2$ = 5.27, *p* = 0.022**). Saint Paul residents had higher odds of having seen or heard any publicity about drivers stopping for pedestrians in crosswalks than Minneapolis residents (**Odds ratio = 1.63, 95% CI = [1.07, 2.48]**; Percent of "Yes": 15.0% versus 11.3%, respectively).

Table 3.18 Awareness of any publicity about drivers stopping for pedestrians in crosswalks

	Yes	No
Phase I (N=497)	6.5% (32)	93.5% (461)
Phase II (N=783)	16.5% (128)	83.5% (647)
Overall (Total N=1280)	12.6% (160)	87.4% (1108)

Q12: *IN THE PAST MONTH, HAVE YOU SEEN ANY ROAD SIGNS ABOUT THE PERCENT OF SAINT PAUL OR MINNEAPOLIS DRIVERS STOPPING FOR PEDESTRIANS?*

Similarly, participants' awareness of the feedback signs was also improved after the intervention program. As shown in Table 3.19, approximately one in four participants (25.4%) reported that they had seen at least one feedback sign in Minneapolis, Saint Paul, or both cities in the Phase II survey, compared to only 5.7% provided a positive response in the Phase I survey. Participants were slightly more likely to report having seen the signs in Saint Paul than in Minneapolis. There was a significant main effect of Study time (**$\chi2$ = 27.11, *p* < .001**).

Respondents was significantly less likely to report having seen the blue feedback signs if they were a non-driver or held a learner's permit (**$\chi2$ = 4.31, *p* = 0.038**), and as their age range increased (**$\chi2$ = 33.12, *p* < .001**).

Table 3.19 Awareness of the feedback signs

	Phase I (N =490)	**Phase II** (N=768)	**Overall** (N=1258)
No, I have not seen them in either city	94.3% (462)	74.6% (573)	82.3% (1035)
Yes, I've seen at least one in Minneapolis	1.2% (6)	8.5% (65)	5.6% (71)
Yes, I've seen at least one in Saint Paul	2.9% (14)	13.5% (104)	9.4% (118)
Yes, I've seen them in both cities	1.6% (8)	3.4% (26)	2.7% (34)

3.4.3 Summary of the Survey Results

The survey results indicated that there was generally no effect of the program in terms of increased knowledge of the crosswalk law or increased perceived safety. There was improved knowledge of the feedback signs and increased knowledge of the program after the program was completed for both cities. There were also significant baseline and post-program differences between Saint Paul and Minneapolis, potentially due to a greater deployment of these signs in Saint Paul.

3.5 CONCLUSIONS AND RECOMMENDATIONS

3.5.1 Engineering & Outreach Program Research Question Summary

The following sections provided evaluations of drivers' yielding outcomes at unsignalized and signalized intersections. Different analytical approaches were utilized with each intersection type, which focused on addressing:

1. Did the outcome differ between the two cities and over time?
    a. For unsignalized intersections, there was a difference between the two cities, with Saint Paul having higher yielding rates than Minneapolis. However, there was no difference across time, when averaging both generalization and treatment sites together. This suggests there was no overall cultural shift in driver behavior at unsignalized intersections in either city because of the program.
    b. For signalized intersections, there was no difference between cities in yielding rates for left turns; however, Saint Paul had a small but statistically significant higher percentage of right-turn yields than Minneapolis. There was no effect of time across both generalization and treatment sites when averaged together. Again, this suggests there was no overall cultural shift in driver yielding behavior at signalized intersections because of the program.
2. How effective were the feedback signs in changing drivers' stopping for (or yielding to) pedestrians in crosswalks?
    a. The feedback signs did not appear to be effective in isolation when deployed across both cities in changing the yielding rates. This was true across both treatment and generalization sites, irrespective of whether the sites were unsignalized or signalized.
    b. The influence of the feedback signs in combination with other engineering countermeasures may have helped to influence driver yielding behavior in Saint Paul at treatment sites, but this effect is not likely to be sustained once treatment is removed.
    c. The influence of the feedback signs was less likely to be influential in improving driver behavior in Minneapolis since the signs were not demonstrating social norms of most drivers yielding to pedestrians. Instead, Minneapolis signs may have been counterproductive since they were communicating that the social norm of most drivers is to not yield to pedestrians.
3. How well did engineering countermeasures work on improving drivers' stopping frequency at various interim stages of the program implementation?
    a. For unsignalized sites, the effectiveness of any interim treatment stage in Saint Paul did not result in significant changes in yielding rates for treatment sites or generalization sites and Minneapolis treatment sites only had marginal improvements during the interim treatment stages. However, there was a significant effect across all treatment

phases compared to baseline for the treatment sites in both cities. This is partially attributable to greater deployment of R1-6 signs, as well as the totality of other treatment methods. This is directly observable in the yielding rates during the final treatment phase, which deployed the greatest use of these signs (see Figures 3.3 and 3.4), multiple signs at a single site, and signs paired with other methods such as temporary pedestrian refuges.

   b. For signalized sites, there appeared to be an effect of treatment phase on treatment sites across both cities for right-turning yielding, when collapsing yielding rates into an ordinal system of five compliance levels and considering the highest versus lowest levels of compliance. As observed over the course of the study, rates of highest compliance appeared to either remain the same or decline for generalization sites, while there was no decline and, in some cases, even improvement in high compliance for treatment sites. It is difficult to determine whether bollards, LPIs, or hardened centerlines had a greater effect, but the bollards and signal timing appeared to have some effect during the interim stages. These effects were primarily restricted to right-turning yielding compliance, with no effects observed for left-turning yielding compliance. However, data regarding left-turning yielding was less frequent than right-turning yielding and may be underestimated in these results.

4. As one integrated program, did the community intervention efforts (including feedback signs and all engineering countermeasures) improve the percentage of drivers stopping for pedestrians?
   a. The entire program appeared to be effective for improving yielding rates for unsignalized treatment sites and reducing very low levels of compliance and increasing the highest levels of compliance for right-turning yielding for signalized treatment sites for both cities. However, no generalization effect was observed with this version of the community intervention program, suggesting that this is best considered as a targeted intervention approach instead of a broadly general intervention approach.
   b. The diminished influence of the community intervention program observed in this study compared to other similar studies may also be related to the absence of police enforcement as a component of the program. The lack of police enforcement to reinforce the importance of the Minnesota Crosswalk Law and help raise awareness of the program may have been a factor influencing the small effects observed in either city.

3.5.2 Survey Results Summary

The survey questions were focused on answering the following research questions. Here is the summarized answer to these responses.

1. Participants' self-reported frequencies of driving and crossing the crosswalk in both cities
   a. Overall, Minneapolis participants who were drivers tended to drive more than Saint Paul drivers, although Minneapolis also reported a higher percentage of participants who did

not drive at all. Saint Paul participants reported crossing crosswalks more often than Minneapolis participants.

2. Perceived risks for different types of crosswalks in both cities
    a. Participants found crossing an unmarked and unsignalized crosswalk to be slightly safer in Saint Paul than in Minneapolis. There was no effect of city or time for other types of crosswalks. Drivers with a driver's license tended to perceive crossing a marked crosswalk with a traffic signal to be safer than those who did not have a driver's license, perhaps reflecting a bias.
    b. Saint Paul residents tended to perceive police enforcing the Minnesota Crosswalk Law more strictly than Minneapolis residents. This effect is likely the result of the higher level of crosswalk enforcement carried out in the past in Saint Paul.
3. Knowledge of the Minnesota crosswalk law
    a. A large percentage (89.6%) of participants across both cities indicated a knowledge of the Minnesota crosswalk law, with no significant difference between survey time or city. However, when asked for specifics such as requirements for drivers at unmarked crosswalks when a pedestrian is present, Saint Paul participants tended to be correct more frequently than Minneapolis participants. This may have larger implications for citywide yielding differences since the city of Minneapolis tends to mark unsignalized crosswalks less frequently than the city of Saint Paul.
4. Awareness of the community intervention program, including the blue feedback signs.
    a. Between the pre-intervention survey and the post-intervention survey, participants in both cities reported greater awareness of publicity for drivers stopping for pedestrians, particularly for Saint Paul residents. Furthermore, both cities also reported a greater awareness of the blue feedback signs in the post-intervention survey, relative to the pre-intervention survey.
5. For signalized marked crossings, the impact of the interventions such as LPIs, bollards, and hardened centerlines have a larger effect on right-turning yielding propensity relative to left-turning yielding propensity. If right-turning yielding is the primary driver behavior of concern, these measures may be effective, but if left-turning yielding is the primary behavior of concern, other interventions may be more appropriate.
6. Other measures that were not considered here may be influenced by the intervention methods, which may need further consideration. For example, use of hardened centerlines, temporary refuge islands, or lane conversions reportedly made crossing “feel” safer or “less hectic” among research staff, although not having a direct effect on yielding rates, perhaps due to making driver behavior more predictable to pedestrians.

CHAPTER 4: DISCUSSION

The results of this study did not find evidence of citywide cultural shifts in either Saint Paul or Minneapolis as a result of the engineering and outreach intervention program, as was found with the previous 2018 study conducted in Saint Paul (Morris et al., 2019) which included an enforcement component, but did find local changes in driver behavior following engineering treatments. It is important to compare and contrast the intervention methods of the current 2021 study against the intervention methods of the previous 2018 Saint Paul study conducted in Saint Paul to provide a more holistic picture of the benefits and potential for implementation of this study's components.

The results of the 2018 study found a significant improvement to both treatment (i.e., enforcement and engineering) sites and generalization sites following program implementation (Morris et al., 2019). More specifically, the 2018 study found significant improvements in both increased yielding (i.e., 32% at baseline and as high as 78% at treated sites and 61% at untreated sites following program implementation) and reduced multiple threat passing. Overall, the 2018 study results suggest a shift in driving culture in Saint Paul since treatment effects appeared to diffuse to non-treated sites.

The 2021 study found modest improvements in yielding at engineering treatment sites, but no improvements at generalization sites. More specifically, driver yielding at unsignalized treatment sites in Saint Paul and Minneapolis significantly increased from baseline measurements of 48.1% and 19.8%, respectively, to 65.5% (i.e., excluding Snelling and Laurel) and 38.8%, respectively, following program implementation. However, generalization site performance in both Saint Paul and Minneapolis slightly decreased from 35.1% and 26%, respectively, down to 31.4% and 24.9%, respectively. Changes at signalized intersections in both Saint Paul and Minneapolis were more modest following treatment. No significant improvements in left or right-turning yielding by drivers in Saint Paul were found at treated signalized intersections but given that yielding was significantly worse at generalization sites over time, there may be some evidence that treatments mitigated performance declines among Saint Paul drivers during the study period. Yielding improvements were more pronounced by only right-turning drivers in Minneapolis at signalized treatment sites, but generalization sites found no improvement or even worsened over time. Overall, the 2021 study results suggest no shift in driving culture in either city but did find some evidence of local, site-specific changes in driver yielding behavior at treatment locations.

While these two studies have many similarities, the differences between the two treatment programs may have impacted their outcomes. The most pronounced differences of the 2021 study and the 2018 study are the absence of enforcement in 2021 as a treatment component, along with the diffusion of treatments across signalized and unsignalized intersections. However, there are a number of other factors to consider when evaluating the extent to which these key differences may have played a role in the study outcomes. The research team has identified all key **public-facing** interventions used in the combined 2018 (Morris et al., 2019) and 2021 programs to improve driver-pedestrian interactions for both unsignalized and signalized intersections. The program in 2021 comprised **outreach, education**, and **engineering** components, while the 2018 program also had an **enforcement** component. The methods of each study are described below. We then discuss how these components were measured and assessed, as well as outline potential confounding variables. Finally, we provide an overview of the most impactful or beneficial components of the program, along with the nature of those benefits.

4.1 METHODS

The treatment methods of the two studies can be classified into four broad categories: outreach, education, engineering, and enforcement and many of the treatment methods can be applicable across multiple categories. Outreach and community engagement were largely comparable across both studies, however, the level of engagement by the media differed with the absence of police enforcement in 2021. Other key differences relate to the absence of police enforcement in 2021 and additional engineering treatments deployed in 2021 at both signalized and unsignalized sites. The methods are categorized based on their primary category or categories of treatment and described below. Table 4.1 summarizes the shared and different treatment methods deployed in the 2018 and 2021 studies and indicates the degree of overlap that each of these methods have across multiple treatment categories.

Table 4.1 Awareness of any publicity about drivers stopping for pedestrians in crosswalks

Method	Outreach	Education	Enforcement	Engineering	2018	2021
Social Media Posts	X	X			X	X
School/Community HVE Flyers	X	X	X		X	
Pledge/Project Fliers	X	X				X
Council/Organization Discussions	X	X			X	X
Presentations	X	X			X	X
Personal Field Outreach	X	X			X	X
Post/Post Survey	X				X	X
Earned Media [Engineering/Outreach]	X	X			X	X
Earned Media [Enforcement]	X	X	X		X	
Feedback Signs	X			X	X	X
New Crosswalk Markings	X			X		X
Bollards				X		X
R1-6 Signs		X			X	X
Hardened Centerline				X		X
Signalized Stop for Ped Signs	X	X		X		X
Enforcement fliers	X	X	X		X	
Warning Wave	X	X	X		X	
Enforcement Wave	X	X	X		X	

4.1.1 Outreach & Education

SOCIAL MEDIA (2018 & 2021). Social media was leveraged in both studies across a variety of platforms including Twitter (the predominant platform used for social media), Facebook, NextDoor, and LinkedIn. Social media posts were made by both MnDOT and the HumanFIRST research team on Twitter to elevate the public awareness of the studies, both in terms of letting the public know about pedestrian crossings and the crosswalk law, as well as the initiation and implementation of the studies itself.

SCHOOL/COMMUNITY HVE FLIERS (2018). These fliers were distributed to community members and schools near the treatment sites to alert community members and parents to the nature of the crosswalk law, importance of yielding farther back from the crosswalk, and the deployment of Saint Paul police to enforce the crosswalk law through the Stop For Me program.

PLEDGE/PROJECT FLIERS (2021). These fliers were distributed to community members to alert them of the study and encourage them to pledge to improve roadway safety by drivers, bicyclists and pedestrians, with an emphasis on behaviors that are related to pedestrian safety, including behaviors that are required by law (i.e., stopping for pedestrians at a crosswalk). The pledge could be committed to by reading the flier or by visiting an online pledge hosted on the study web page and Qualtrics.com.

COUNCIL / ORGANIZATION DISCUSSION (2018 & 2021). The research team reached out to neighborhood and district council members across the two cities and discussed with them any concerns they had regarding the study as well as potential opportunities to raise awareness within the local neighborhoods on the study and share study outreach materials.

PRESENTATIONS (2018 & 2021). Presentations about the study, both for preliminary findings as well as general communication, were conducted for regional audiences including people that lived within the Twin Cities. Presentations were made for both the 2021 study and the 2018 study.

PERSONAL FIELD OUTREACH (2018 & 2021). Whenever the research team members were conducting staged crossings, they would occasionally interact with interested community members. When this occurred, they would let the interested community member know about the study and its details as well as distribute a flier if one was on hand.

SURVEYS - PRE/POST (2018 & 2021). Before and after the primary interventions were administered for both studies, a pre-intervention survey was distributed to people that lived in the Twin Cities area. Then, once the intervention portion of the study was completed, a post-intervention survey was distributed. The survey asked about perceptions of safety (2021 survey only), awareness of feedback signs, enforcement, and knowledge of the crosswalk law.

ENGINEERING/OUTREACH (2018 & 2021). Whenever the local or regional media organizations would reach out for an interview either for television, print, or radio/podcast, particularly when motivated by the presence of feedback signs, engineering, or word of mouth, this constituted earned media which was intended to raise awareness of the study and improve knowledge of the crosswalk law. The research team also coordinated with local and state partners to distribute press releases to help garner more media interest regarding the studies and stages or phases within the studies.

ENFORCEMENT (2018). The earned media aspects for the 2018 study were similar, although occasionally motivated by the presence of increased police enforcement and the Stop For Me program.

FEEDBACK SIGNS (2018 & 2021). Feedback signs for both studies were placed in high volume traffic corridors, communicating the record percent yielding and the most recent yielding numbers for the previous week. Eight Saint Paul signs were deployed across eight locations, while six Minneapolis signs were deployed across four locations. Numbers for the 2021 study reflected a weighted average of the signalized and unsignalized sites for yielding percentage. The numbers for the 2018 study reflected averages from unsignalized sites only. Notably, the feedback signs in 2018 presented percentages near or above 50% which would be most effective for social norming. The feedback signs in the 2021 study often displayed above 50% yielding for Saint Paul drivers, but never displayed values above 50% for Minneapolis drivers (i.e., displayed percentages ranged from 25% to 48%) which would be ineffective in achieving desired social norming changes.

4.1.2 Engineering

NEW CROSSWALK MARKINGS (2021). Crosswalk markings, specifically their presence and type, were considered, particularly in the 2021 study in Minneapolis, given that Minneapolis has a lower count of crosswalk markings at unsignalized crosswalks. All sites in Saint Paul for both the 2018 and 2021 studies had an existing crosswalk marking which may have required a refreshing of the marking, but not installation of a new marking.

BOLLARDS (2021). These were inexpensive plastic bollards installed at both signalized and unsignalized crosswalks, either to act as temporary curb extensions or as lane conversions and pedestrian refuge islands.

R1-6 STATE LAW STOP FOR PEDESTRIANS SIGNS (2018 & 2021). These in-street signs act as an alert to remind drivers of the potential presence of pedestrians, while also reinforcing the requirement to stop for them if they are present. They were either placed singularly, usually in the median, or grouped together with other R1-6 signs adjacent near the curb or other lane lines.

HARDENED CENTERLINES (2021). Some orange-colored bollards were placed in the center of lane lines to act as a traffic calming measure at signalized treatment intersections.

R10-15 TURNING DRIVERS STOP FOR PEDESTRIAN SIGNS (2021). These signs were placed on signalized treatment intersections, usually on the road with the most traffic volume, which intended to remind drivers to stop for pedestrians when turning right.

4.1.3 Enforcement Activities (2018)

ENFORCEMENT FLIERS (2018). When police would pull over drivers for violating the crosswalk law, they would distribute fliers similar to the fliers disseminated to schools.

WARNING WAVE (2018). The initial wave of enforcement in 2018, conducted over two weeks at treatment sites, used warnings instead of citations in order to elevate awareness of the program and the law without significant consequences for violators.

ENFORCEMENT WAVES (2018). These waves were similar to the warning waves but employed actual citations. Because citations take longer to administer than warnings, the throughput of violators to citation was reduced relative to the throughput of violators to warnings.

4.2 METHOD MEASUREMENT AND ASSESSMENT

The methods for measurement and assessment were similar across the 2018 and 2021 studies; however, given the differences in treatments and site locations, there were several measures that differed between the two studies. One measurement category missing from the 2021 study was enforcement metrics (i.e., measure of warning and citations issued). Measurement categories missing from the 2018 study were perceptions of safety by pedestrians (i.e., measured in 2021 only) and types of yielding (i.e., signalized vs unsignalized locations). An overview of study metrics by treatment category is shown in Table 4.2. Similar to treatments, these measurements often overlap multiple categories, and they are listed in greater detail below according to their primary category or are duplicated across multiple categories when categorical aspects of their findings are distinguishable.

Table 4.2 Comparative chart of measurement and assessment methods by classification type in 2018 and 2021 studies

Method	Outreach	Education	Enforcement	Engineering	2018	2021
Earned Media Count	X				X	X
Knowledge of Feedback Signs	X				X	X
Yielding Generalized	X	X			X	X
Multiple Threat Passing (and other)	X		X	X	X	
Police Warning Count	X		X		X	
Knowledge of Crosswalk Law		X			X	X
Knowledge of Enforcement	X		X		X	X*
Enforcement Stop Count			X		X	
Yielding Treatment			X	X	X	X
Perception of Crosswalk Safety	X	X	X			X
Citation Count			X		X	

4.2.1 Outreach Assessment

EARNED MEDIA COUNT (2018 & 2021). Local, regional, or national news stories were tracked during both studies to determine the extent to which pedestrian or roadway safety issues, as applicable to the study and/or research team, were covered by news agencies. This tracking served as a proxy measure for the reach of community engagement on the topic. The 2018 study was linked to a higher number of news stories (i.e., 24) than the 2021 study (i.e., 16). Notably, the 2018 stories often contained coverage of increased police enforcement, which was absent in the 2021 study.

KNOWLEDGE OF FEEDBACK SIGNS (2018 & 2021). The impact of the feedback signs was partially measured through community member stated knowledge of the signs. In both studies, surveys captured knowledge of the signs before and after their deployment. In the 2018 study, 4% of respondents reported having seen the signs (prior to their installations) and this percentage grew to 37% following their installation. The same metric was tracked in the 2021 study across community members of both Saint Paul and Minneapolis. Community members of both cities reported a greater awareness of the blue feedback signs in the post-intervention survey (25.4%), relative to the pre-intervention survey (5.7%). Notably, there were more signs installed in Saint Paul (i.e., 8 locations) than in Minneapolis (i.e., 4 locations) which mirrored higher reporting of having seen the signs in Saint Paul (16.9%) than in Minneapolis (11.9%).

DRIVER BEHAVIOR METRICS

YIELDING AT GENERALIZED SITES (2018 & 2021). A significant increase in driver yielding was found at generalization sites in the 2018 study. However, no generalization effect was observed with the 2021 version of the community intervention program, suggesting that the 2021 intervention program is best considered as a targeted intervention approach rather than a broad or general intervention approach.

MULTIPLE THREAT PASSING, ETC. (2018). The overall rate of other violations including multiple threat passing was relatively low in 2021 and not amenable to statistical analysis for considering intervention effectiveness. Notably, the tipping point for multiple threat passing to occur at a higher measurable rate in Minneapolis during the 2021 study may not have been reached due to lower overall yielding in the city (i.e., an initial yield is required before a multiple threat pass can occur). In contrast, the rates of multiple threat passing were observed to significantly decrease in the 2018 study in Saint Paul, possibly due to higher initial rates observed (i.e., in combination with higher yielding) and increased awareness due to enforcement utilizing the public endangerment option should multiple threat passing occur, which would force violators to show up in court. The current study may suggest maintenance of multiple threat passing reductions in Saint Paul over time which is notable given the higher number of Saint Paul sites with multilane roads which are typically high risk for this type of passing.

ENFORCEMENT ENGAGEMENT

POLICE WARNING COUNT. In total, 1,112 warnings were issued during the initial warning period in the 2018 study. These warnings afforded Saint Paul Police to communicate with drivers about the law for stopping for pedestrians and share an enforcement flier. These points of interaction were hypothesized to result in a more receptive response from drivers since they were engaged with only a warning and not a citation.

4.2.2 Education Assessment

KNOWLEDGE OF CROSSWALK LAW (2018 & 2021). Community survey responses for the 2021 study found that 89.6% of participants across both cities indicated a knowledge of the Minnesota crosswalk law, with no significant difference between survey time, although Saint Paul residents tended to be more accurate with the specifics. These percentages largely matched the results from the 2018 pre-post survey results which also found a high percentage of respondents accurately reporting crosswalk law knowledge, 88% and 90%, respectively, and no significant differences by survey time.

KNOWLEDGE OF ENFORCEMENT (2018 & 2021*). There was no significant difference in the 2018 study about knowledge of specific enforcement activities near their location, but there was a higher reported awareness of study activities overall. While there were no corresponding enforcement activities associated with the 2021 program by which the research team could measure enforcement knowledge, the survey did assess perception of crosswalk law enforcement stringency in each city. There was a significantly higher perception of enforcement of the Minnesota Crosswalk law by law enforcement in Saint Paul compared to Minneapolis. This is likely attributed to the ongoing activities of the Stop For Me program by the Saint Paul Police Department and overall policy to enforce the law in the city compared to the absence of such programs or policies by the Minneapolis Police Department.

4.2.3 Engineering Assessment

YIELDING AT TREATMENT SITES (2018 & 2021). The effect of treatment in the 2018 study was pronounced (i.e., as low as 26% in baseline and as high as 78% in treatment). The increase in yielding was most pronounced following the deployment of the R1-6 gateway treatment at unsignalized sites, but largely attributed to the combined, phased intervention program (i.e., enforcement, education, and engineering). For the 2021 study, there was a significant effect across all treatment phases compared to baseline for the unsignalized treatment sites. This is partially attributable to greater deployment of R1-6 signs, as well as the totality of other treatment methods. For signalized sites, there appeared to be an effect of treatment phase on treatment sites across both cities for right-turning yields. These effects were primarily restricted to right-turning yielding compliance, with no effects observed for left-turning yielding compliance. It’s difficult to determine whether right-turn signs, LPIs, or hardened centerlines had a greater effect, but the signs and signal timing appeared to have some effect in the interim stages. Continental markings were added to eight initially unmarked unsignalized crosswalks in Minneapolis two weeks after baseline coding began. The first weeks of baseline measurement without crosswalk markings were compared to the weeks of baseline measurement with crosswalk markings, and there was a significant improvement of approximately 11% in the yielding rate after markings were added (12% to 23.6%).

MULTIPLE THREAT PASSING, ETC. (2018). The 2018 study interventions (R1-6 signs and gateways) may have had some effect on reducing high multiple threat passing rates observed at unsignalized intersections. The pre-existing presence of advance stop bars at study locations was also associated with lower multiple threat passing during the 2018 study. The overall rate of multiple threat passing and other high-risk behaviors (e.g., hard braking) was relatively low in 2021 and not amenable to statistical analysis for considering intervention effectiveness. Advance stop bars were installed at some study locations in Saint Paul, but limited deployment of this treatment and lower overall incidence of multiple threat passing in Saint Paul resulted in inconclusive results regarding the strength of treatment in reducing high risk driving behaviors.

PERCEPTION OF CROSSWALK SAFETY (2021). The 2021 study survey assessed community members' perceptions of safety within different types of crosswalks (i.e., marked and unmarked unsignalized intersections and signalized intersections). This assessment was not completed in the 2018 study. While a number of pre-existing factors were found to predict higher perceived safety in unsignalized crosswalks (e.g., living in Saint Paul and being older, male/non-binary, and/or having a driver's license), there were no time-based factors that resulted in greater perceived safety in either city. This suggests that there was not an increased global sense of pedestrian safety among community members of either city following the engineering treatment of the 2021 study. Again, such findings may suggest that the 2021 version of the program is suited for targeted interventions rather than as a citywide program.

4.2.4 Enforcement Assessment (2018 Study)

ENFORCEMENT STOP COUNT (2018). The research estimates that there were over 2,500 stops made during enforcement in the 2018 study when summing the citations in the latter three phases of the study and the warnings issued during all four phases. This measure helped to indicate the degree to which the enforcement program had high visibility in terms of directly engaging with violating drivers and the observation by other drivers that this enforcement was underway. Additionally, SPPD used signage directed at passing traffic to alert drivers that drivers were being stopped for failing to stop for pedestrians.

CITATION COUNT (2018). Following the first warning wave, 1,267 citations were issued during the successive three phases of enforcement in the 2018 study. Such metrics helped to demonstrate the scale of intervention of the enforcement component of the program. While educational flyers were distributed by police during citations, they were hypothesized to be less salient than the citation issued, especially those that added additional penalty of court appearance for multiple threat passing.

YIELDING AT TREATMENT SITES (2018). The observed impact of yielding increases with the first two enforcement waves (i.e., warning wave and citation wave #1) was modest in the 2018 study. Yielding at treatment sites remained relatively flat (i.e., ~50%) during and in the weeks after the enforcement treatment waves. Yielding at treatment locations did not markedly increase until the first engineering treatment (i.e., single R1-6 signs) was implemented along with community feedback signs and the third enforcement treatment wave at study locations. Yielding at treatment sites exceeded 70% during the final phases of the study which combined enforcement with the R1-6 gateway configuration treatment, as well as community feedback signs. These results suggested that enforcement alone, or at least two waves of enforcement, was insufficient to change driver yielding behavior and that the combined program of enforcement, outreach, and engineering, particularly the R1-6 signage treatments, were responsible for the significant improvements in yielding behaviors at treatment and generalization sites.

MULTIPLE THREAT PASSING, ETC. (2018). Reducing multiple threat passing was a key focus of both outreach and enforcement treatments. Multiple threat passing was close to 12% per 20 crossings at the beginning of the 2018 study and was generally less than 5% per 20 crossings toward the end of the study. While this metric may have corresponded with improved yielding overall, the success in reducing these high-risk passing behaviors was largely attributed to the novel enforcement approach of requiring offending drivers to appear in court when cited for the behavior.

4.3 CONFOUNDING FACTORS

There are a number of confounds between the 2018 and 2021 studies which complicate their comparison beyond simply considering methodological differences in the studies. These confounds may have exacerbated risky driving behaviors, making engineering treatments less successful. Additionally, these confounds may have limited the outreach and resultant uptake of the outreach messaging due to competing topics related to public safety. These confounds are summarized below in Table 4.3 to demonstrate the categories of treatment that they may have impacted and which study they may have influenced.

Table 4.3 Comparative chart of study confounds by classification type in 2018 and 2021 studies

Confounding Variables	Outreach	Education	Enforcement	Engineering	2018	2021
Community-Police Relations	X					X
COVID-19 (behavior, baseline)	X		X			X
2018 Midterm Elections	X				X	
Construction				X	X	X
Citywide speed limits				X		X
Seasonal/Time/Weather	X			X	X	X
Stop For Me			X			X

4.3.1 Outreach & Education Confounding Factors

COMMUNITY-POLICE RELATIONS (2021). The relationship between community members and policing actions were more strained in 2021 than in 2018. The primary difficulty this posed to the study was inability to use enforcement as a treatment component in the 2021 study and instead resulted in a primary focus on engineering and outreach instead. Beyond this, strained community-police relations may have impacted the ability to provide significant outreach and education regarding pedestrian safety, particularly through earned media channels, as the media and public attentional bandwidth was occupied by other matters instead of pedestrian safety (i.e., murder of George Floyd and subsequent trial of Derek Chauvin). The 2018 study treatment phases were preceded by a planned "media blitz" to increase awareness of pedestrian safety issues; however, this same period for the 2021 largely coincided with the Derek Chauvin trial, along with COVID-19 news, which limited opportunities for media attention.

COVID-19 (2021). The 2020-2021 pandemic affected life significantly, disrupting the planned study schedule, traffic patterns, and pedestrian behavior. Disruptions to in-person working at the University of Minnesota and travel patterns (i.e., decreased vehicle and pedestrian traffic) restricted the research team's ability to conduct a baseline data collection period in the fall of 2020. Limiting the baseline data collection period to the spring of 2021 limited the research team's ability to consider seasonal influences in baseline and treatment data collection periods as well as reduced the ability to plan targeted engineering interventions based on baseline study findings, as was done in the 2018 study. Furthermore, given the amount of warranted media attention toward the pandemic, other issues such as pedestrian safety may have not successfully competed for public attention, as evidenced by reduced media coverage for the 2021 study. Finally, high-risk traffic behaviors were observed to increase following the COVID-19 pandemic. Notably, speeding related deaths increased in Minnesota and social distancing considerations may have influenced law enforcement agencies to conduct fewer traffic stops. Overall, increased speeding behaviors in both Minneapolis and Saint Paul are likely to have coincided with lower driver yielding behaviors which may have limited the efficacy of study treatments.

2018 MIDTERM ELECTIONS (2018). While at a smaller scale, the 2018 midterm election was underway during the final portion of the 2018 study, which may have also competed with media interest and public attention.

4.3.2 Engineering Confounding Factors

CONSTRUCTION (2018 & 2021). Construction changed traffic patterns and behavior and affected the ability for the engineering interventions to reliably improve driver behavior toward pedestrians. Construction and maintenance were limiting factors for data collection in the 2018 study and resulted in the loss of a treatment site (i.e., Maryland & Walsh) following a road re-pavement and removal of crosswalk marking. Similarly, the 2021 study was also impacted by construction near study sites in both Saint Paul and Minneapolis. Construction influenced treatment installation delays in Minneapolis which may have had detrimental effects in that city. Similarly, construction resulted in traffic backups that reduced the efficacy of nearby treatments. This was especially apparent for the R1-6 gateway configuration signs on Snelling & Laurel in Saint Paul and for bollards treatments at Chicago & 15th in Minneapolis.

CITYWIDE SPEED LIMITS (2021). Both Minneapolis and Saint Paul implemented citywide speed limits of 20 mph in November 2020, i.e., just prior to the 2021 data collection. The extent to which this change impacted driver behaviors (e.g., speed, speeding, yielding, acceptance/rejection of engineering treatments) is unclear. The research team used the new posted speed limits (which varied from 20 mph to 30 mph) to calculate the dilemma zones (i.e., using ITE signal timing formula) at unsignalized intersections. Notably, all study locations in the 2018 study had a posted speed limit of 30 mph. The 2021 study calculations may have underestimated the required distances needed for braking in response to pedestrians in a crosswalk among drivers failing to comply with new lower posted speed limits. Presumably lower speeds would increase yielding, but given the recent nature of the change, it's not certain whether detrimental effects had occurred or affected the baseline data in Saint Paul in 2021 compared to 2018. Furthermore, it's not clear how much the likelihood of increased speed differentials, caused by some drivers still following a 30-mph velocity compared to other drivers or by failing to slow down appropriately after departing a road with a higher speed limit, would have impacted likelihood of yielding. Since neither Saint Paul nor Minneapolis have released data or findings on speed studies following the reduced citywide speed limits, it is not clear whether there was greater speeding above the posted speed limits during the 2021 study compared to the 2018 study or what role the lower speed limits may have had in this difference.

SEASONAL/TIME/WEATHER (2018 & 2021). Seasonal patterns may influence the presence of pedestrian traffic and influence whether drivers expect if pedestrians will be present, which will impact whether drivers will be more likely to attend to crosswalks and yield. Such influences include warmer weather, which increases the likelihood of pedestrians being present, as well as the spring and fall school semester, which increases the likelihood of students being present. The impact of school semesters may increase vehicle traffic as well, causing downstream effects on yielding behavior. The extent to which these factors may have influenced results of either study is not known but should be considered in future studies.

4.3.3 Enforcement Considerations

STOP FOR ME (2021). The Stop For Me program continued independently of the study program for Saint Paul in 2021, although the scale of the program was significantly diminished due to low staffing among the traffic enforcement division and COVID-19 social distancing considerations. Nonetheless, it is possible that this continued enforcement tangentially affected yielding behavior towards pedestrians in Saint Paul for the treatment and generalization sites, although any effect would be difficult to disentangle from the prior history of police enforcement.

4.4 CURRENT STUDY LIMITATIONS

Beyond the confounds which constrain the comparability of the current study to the past 2018 study by Morris et al., (2019), there are several limitations to consider in interpreting the current study's findings. These limitations can be identified within the unsignalized and signalized data collection methods, engineering implementation, and engineering maintenance.

4.4.1 Data Collection Methods

The limitations of the unsignalized intersection examination includes data collection coding variability and variability in engineering treatments. Data collection may have been vulnerable to inconsistencies due to coder variability influenced by inter-rater reliability issues in determining yielding conflict qualifications (e.g., interpreting if a driver was beyond the dilemma zone prior to failing to yield). The demeanor of the staged pedestrian may also have varied across research team members, with some team members approaching the crosswalk with greater assertiveness than others, thus influencing driver decision making (Shaon et al., 2018). Differences in assertiveness may have had an interaction with available pedestrian infrastructure. Notably, a lead researcher noted that some coders/staged pedestrians appeared to be hesitant to use the temporary bump outs to their fullest extent (i.e., standing fully within them as they would a permanent bump out) and would only step one foot into them. This variability in the use of the temporary bump outs may have influenced data reliability but may also indicate a potential limitation of the strength of this treatment to allow pedestrians to be better seen by drivers.

The visible characteristics of coders and staged pedestrians such as racial differences or dark skin tones could have also influenced driver behavior with lower yielding rates to them compared to white or light-skinned coders (Goddard et al., 2015; Coughenour et al., 2017). This variability may have also influenced yielding rates in response to natural pedestrians, particularly given the differences in racial demographics across the various study site regions of both Minneapolis and Saint Paul. Gender differences across coders, staged, and natural pedestrians may have also influenced driver behavior with female pedestrians receiving higher yielding rates (Zafri et al., 2022). Gender issues were also suspected to limit the validity of the looking data measured at signalized intersections in this study. Specifically, female decoy pedestrians reported a perception that male drivers appear to look at them more often than male decoy pedestrians and in a manner that was different than simply looking for pedestrians. Beyond this, female coders experienced multiple instances of verbal harassment from male drivers and pedestrians while they were at study locations.

The signalized intersection yielding data was limited with inconsistent pedestrian volumes across study sites. Some locations (e.g., Fork Parkway & Cleveland) had high pedestrian volumes and allowed greater data capture of yielding and non-yielding events, but others had low volumes (e.g., White Bear Ave & Maryland Ave) with infrequent natural pedestrians observed during data collection sessions. Additionally, some locations were more prone to pedestrian violations (i.e., walking against the signal) than others, however, the research team was unable to fully capture pedestrian compliance behavior under the current coding methodology.

Finally, a limitation of this study was the lack of data regarding travel speeds. The research team did not directly measure travel speeds, but there were multiple instances in which coders reported the perception that drivers were traveling at excessive speeds through study sites (e.g., estimated to be traveling up to 50 mph on 25 mph posted roadways). According to the Minnesota Department of Public Safety, 35% of Minnesota's fatal crashes in 2021 were speeding related compared to 30% in 2018 (MN DPS, 2018; 2022). This may suggest that speeding was more frequent during the 2021 study, compared to the 2018 study, and the extent to which drivers were traveling above the posted speed limit was greater with the reduced citywide speed limits in both Minneapolis and Saint Paul. However, without better access to speed study data or direct speed measures, the conclusions about the role that speeds and speeding had on study results is unknown.

4.4.2 Engineering Implementations and Maintenance

There are study limitations to consider regarding the implementation and maintenance of the engineering treatments of this study. The most significant limitation is related to the inconsistency of treatment type and installation schedule across the study locations. These inconsistencies limited the statistical power in observing driver behavior changes to a single treatment type with few locations receiving the same treatment and one treatment site being delayed entirely so that it never received any treatment. Of those that did receive the same treatment, there was variability in the installation dates of these treatments which diffused the observed changes in treatment onset across weeks or months. Additionally, the temporary engineering treatments employed in this study (i.e., bollards and R1-6) were often vulnerable to damage by errant drivers striking or running them over. Repairing the treatments in a timely manner and through the duration of the treatment period of the study was difficult and costly to both participating cities.

The deployment of the feedback signs in Minneapolis while Minneapolis yielding numbers were quite low was also a limitation of this study. Past research studies have deployed these signs after other treatments (e.g., police enforcement) had been in place and yielding numbers had nearly reached or exceeded 50% yielding. While it was an important methodological control to deploy the signs at the same time in both cities, deploying the Minneapolis feedback signs when the yielding numbers were demonstrating only 20-30% of drivers are stopping for pedestrians may have hindered the efficacy of the overall program by communicating risky social norms. Given the low yielding numbers displayed on the signs in Minneapolis, it is unclear whether it was a limitation or benefit that there were fewer feedback signs installed in Minneapolis and that those signs were often less visible due to being knocked over by the wind.

Further, some treatments may have influenced driver behavior changes which were not measured in this study. Specifically, the hardened centerlines at signalized intersections may have slowed turning speeds and modified turning angles; however, these performance changes were not able to be captured under the current study's coding methodology.

4.5 FUTURE RESEARCH

Future research should consider the findings and limitations of this study to further understand which treatments could support a community intervention to improve driving culture to benefit pedestrian safety. Exploring the costs, benefits, and limitations of coding video data compared to staged crossings and field data collection would be beneficial to determine the optimal data collection methods to ensure usable data regarding pedestrian-driver conflicts. Should video data methods for a study of this type be feasible, examining vehicle speeds and turning angles may be useful to better understand the benefit of treatments used in this study (e.g., hardened centerlines) and others not used. Further, future studies should further examine the efficacy of temporary bump outs compared to permanent bump outs relating to pedestrian use and interactions of use with driver yielding behaviors.

Other future research studies should explore the relationship between yielding metrics at signalized and unsignalized intersections and pedestrian crashes to better understand risk factors for intersections with low or high yielding rates. These studies should also further explore the relationships between community crosswalk law knowledge, police enforcement of the law, yielding, crash rates, and educational programs. Given the current paucity of research on the influence that police enforcement programs or enforcement activities in general influence citywide changes in driving behavior and crash risks, future research should continue to examine the influence of police enforcement, as well as explore the efficacy of short duration vs. prolonged enforcement activities, on driver behavior and pedestrian safety. It is important to further this research to optimize future investments in engineering, enforcement, and educational programs to achieve their intended goals of reducing pedestrian crashes and enhancing walkable communities.

Finally, given the pronounced increase in speed-related fatal crashes and pedestrian fatalities in Minnesota (MN DPS, 2022), further research should explore the influences of posted speed limits, travel speeds, and speeding on pedestrian safety. It is critical to determine if lower speed limits can successfully reduce driver speeds and speeding and, in turn, improve pedestrian safety by increasing driver yielding and reducing pedestrian-involved crashes. Future studies should aim to determine which traffic calming engineering treatments (e.g., reduced lane width, road diets, curb extensions, and hardened centerlines) are most effective at reducing travel speeds and increasing driver yielding to pedestrians. Finally, studies examining the efficacy of high-visibility enforcement (HVE) programs targeting speeding drivers and/or automated speed enforcement (i.e., speed cameras) should also examine what influence they may have in increasing driver yielding and pedestrian safety overall.

CHAPTER 5: CONCLUSIONS

5.1 SUMMARY

For the purposes of increasing yielding rates for both signalized and unsignalized crosswalks, deploying a city-wide program of this type over a 7-month period across a large metropolitan area did not appear to be effective in broadly changing or impacting the driving culture throughout the metropolitan area. This may be due to the lack of police enforcement being part of the program or insufficient public awareness and earned media due to other major cultural issues (e.g., socio-political issues, COVID-19, etc.) occurring during deployment of the program.

For the purposes of improving yielding rates and yielding compliance for targeted treatment sites, the community intervention program appeared to be effective, and this effect was observed for both unsignalized sites (to a greater extent) and signalized sites (to a lesser extent). The effect for unsignalized sites appeared to be predominantly observed with the presence of R1-6 signs, but other treatments, including bollard treatments, appeared to also influence driver behavior when yielding. The effect for signalized sites was predominantly observed for right-turning yielding, which was a focus for some of the interventions, but also potentially due to other factors, such as reduced attentional demands on right-turning drivers, as compared to left-turning drivers, allowing them to notice pedestrians and be affected by the intervention strategies.

5.2 RECOMMENDATIONS

Given the previously reported results, the research team provides the following recommendations along with some cost considerations for implementation planning:

1. If police enforcement is not being jointly employed, or there are significant socio-political issues occurring in the city or region, this type of program appears to have a local effect instead of a general effect when treating crossing sites, at least when employed for shorter durations (e.g., 6-7 months). Programs aimed at community-wide improvements in driver yielding to pedestrians should consider leveraging community-supported high-visibility enforcement as a treatment component, along with engineering and outreach treatment phases. However, such programs should be widely announced in advance and should use warning phases, rather than ticketing, to increase community support and reduce community-police tensions. Furthermore, having community members present (e.g., commonly done with SPPD Stop For Me events) during high-visibility enforcement events may help to improve community acceptance of the enforcement of the crosswalk law, as well as increase police accountability during the stops.
2. For unsignalized marked crossings, multiple R1-6 signs, or use of specific temporary pedestrian infrastructure (e.g., bollards and refuge islands) appears to improve yielding to pedestrians at these crosswalks. Limiting R1-6 sign treatments to low-speed, 2-3 lane roadways may decrease maintenance needs compared to expected maintenance needs when applied to 4-lane or more roadways with high-travel speeds. Initial costs and ongoing maintenance costs should be

considered for these treatments. The R1-6 signs are estimated to cost $360 each (up to $1,240 with labor of installation and maintenance included over 3 months from August through October, Morris et al., 2019). Plastic bollards can range from $60 to $200 depending on quality and features.

3. For unsignalized marked crossing treatments (e.g., R1-6 signs), other factors such as construction or high traffic volumes/speeds may counteract any positive effects of the engineering treatment. Increasing maintenance and allocation of resources should be planned during construction, maintenance, or non-recurring high-capacity events for adequately maintaining and restoring damaged pedestrian infrastructure resulting from the associated traffic disruptions.
4. Marking unsignalized crosswalks appears to increase driver yielding to pedestrians but markings in isolation are insufficient to increase yielding to high levels if baseline levels were quite low. Additionally, marking crosswalks in the absence of other crosswalk treatments on high-speed (e.g., 35 mph and over) and multilane roads (e.g., 4 lane or greater roads) may increase pedestrian crash risks and is not advised (Zegeer et al., 2001; Zegeer et al., 2004). Marking crosswalks with high-visibility markings (i.e., continental or zebra style markings) is estimated to cost an average of $770 (up to $3,600) including labor and materials (Bushel et al., 2013).
5. For signalized marked crossings, the impact of the interventions such as LPIs, right-turn signs, and hardened centerlines have a larger effect on right-turning yielding relative to left-turning yielding. If right-turning yielding is the primary driver behavior of concern, these measures may be effective, but if left-turning yielding is the primary behavior of concern, other interventions may be more appropriate.
6. Feedback signs, when used in isolation, do not appear to affect driving behavior or driver culture. They may have an effect when used jointly with other intervention methods. Additionally, they should not be displayed until other treatment methods have increased measured yielding behaviors to near or above 50%. Depending on the size, the costs may range from $800 to $1200 per sign, including the feedback signs used over the course of the study.
7. Any increase in yielding is assumed to reduce the likelihood of a pedestrian crash, although the strength of this relationship is not clear. Pedestrian injuries are estimated to cost $58,700 per event, while fatalities are estimated to cost society $4,538,000 per death (Xie et al., 2017).
8. Posted speed limits should be compared to actual travel speeds (i.e., via speed studies) to better assess pedestrian crash risks and determine what other possible countermeasures should be implemented to reduce driver speeds, increase yielding rates, and reduce pedestrian fatal crash risks.
9. Other measures that were not considered here may be affected by the intervention methods, which may need further consideration. For example, use of hardened centerlines or temporary refuge islands reportedly made crossing “feel” safer, although not having a direct effect on yielding rates, perhaps due to making driver behavior more predictable to pedestrians and reducing the distance pedestrians must cross at once.

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APPENDIX A

SITE IMAGES: SAINT PAUL

Note: These images may not reflect current markings or design

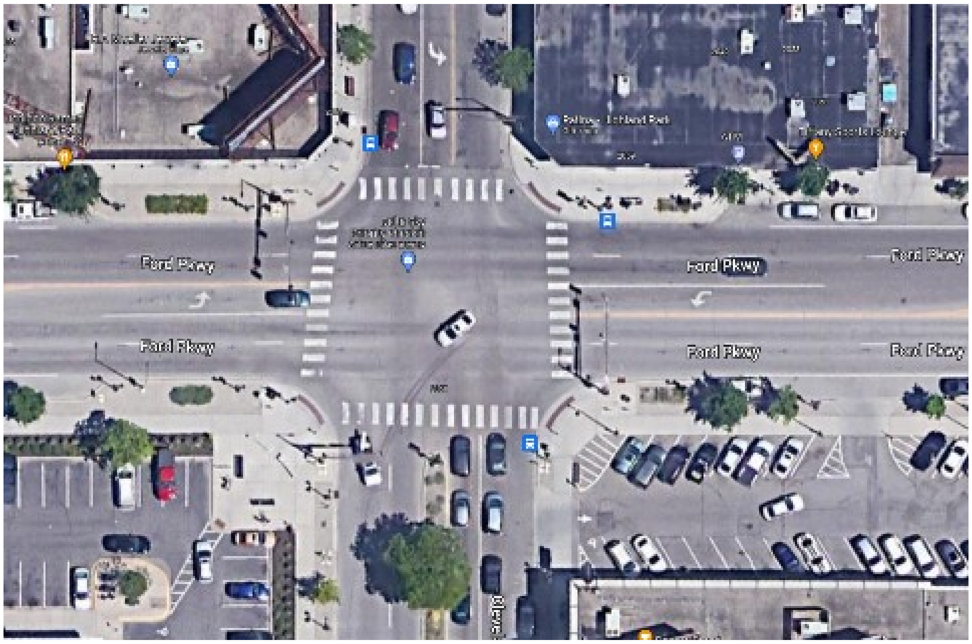
Snelling & Selby

Snelling & Laurel

W 7th & St Clair

W 7th & Michigan

Ford Pkwy & Cleveland Ave S



Cleveland Ave S & W Pinehurst Ave

Maryland & Arcade

Arcade & Jessamine

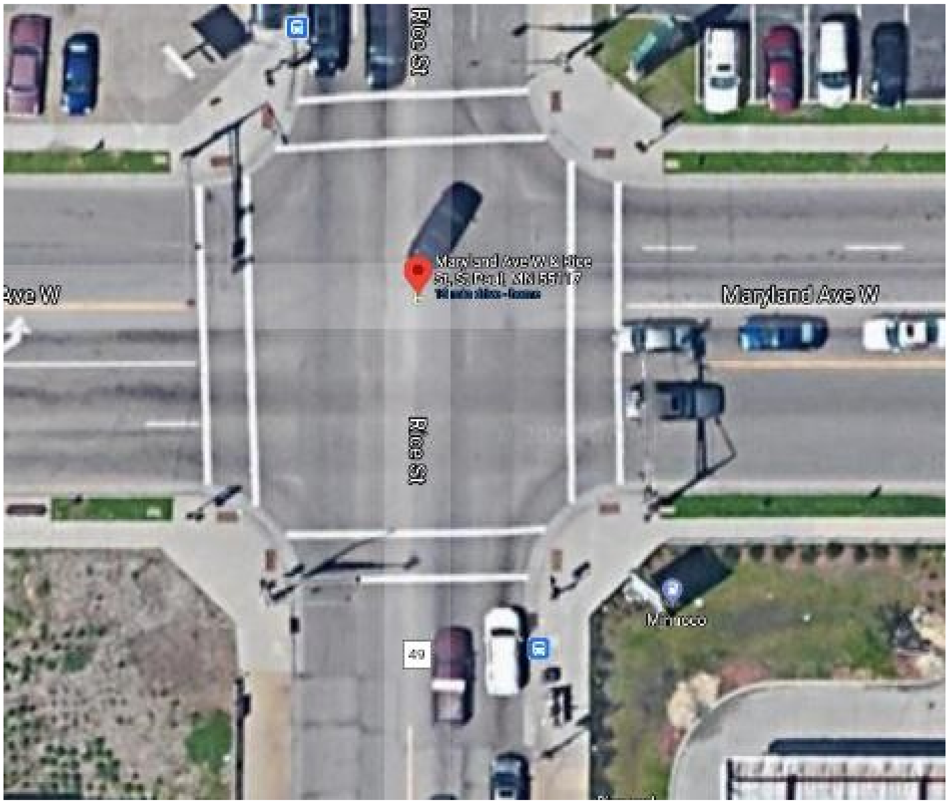
Larpenteur & Rice

Larpenteur & Woodbridge

University & Dale

University & Arundel

Maryland & Rice



Maryland & Woodbridge

White Bear & Maryland

White Bear & Sherwood Ave

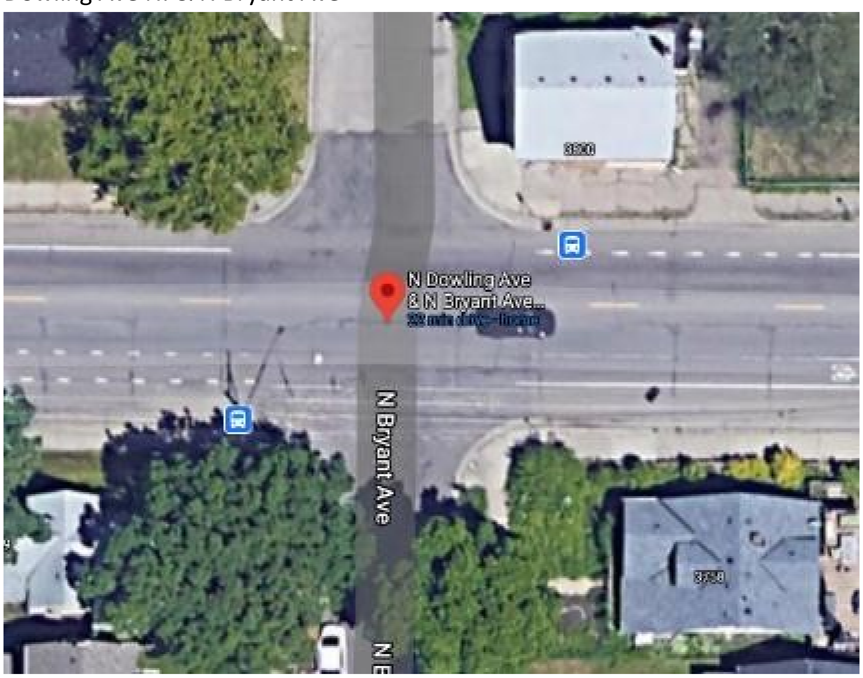
APPENDIX B

SITE IMAGES: MINNEAPOLIS

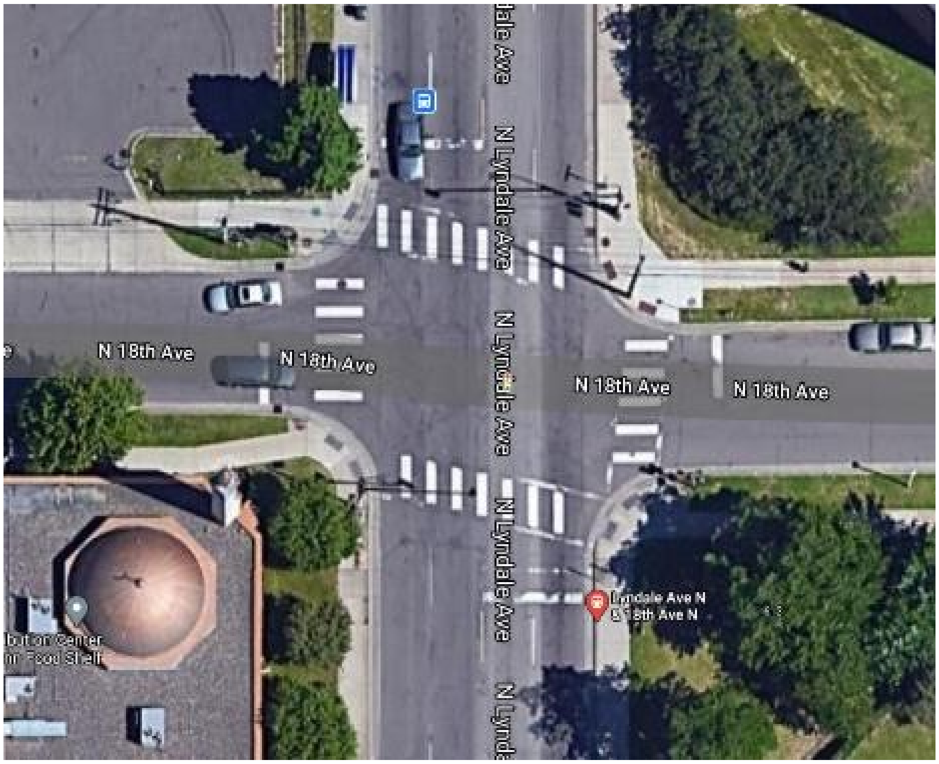
Note: These images may not reflect current markings or design

Lyndale Ave N & Dowling Ave N

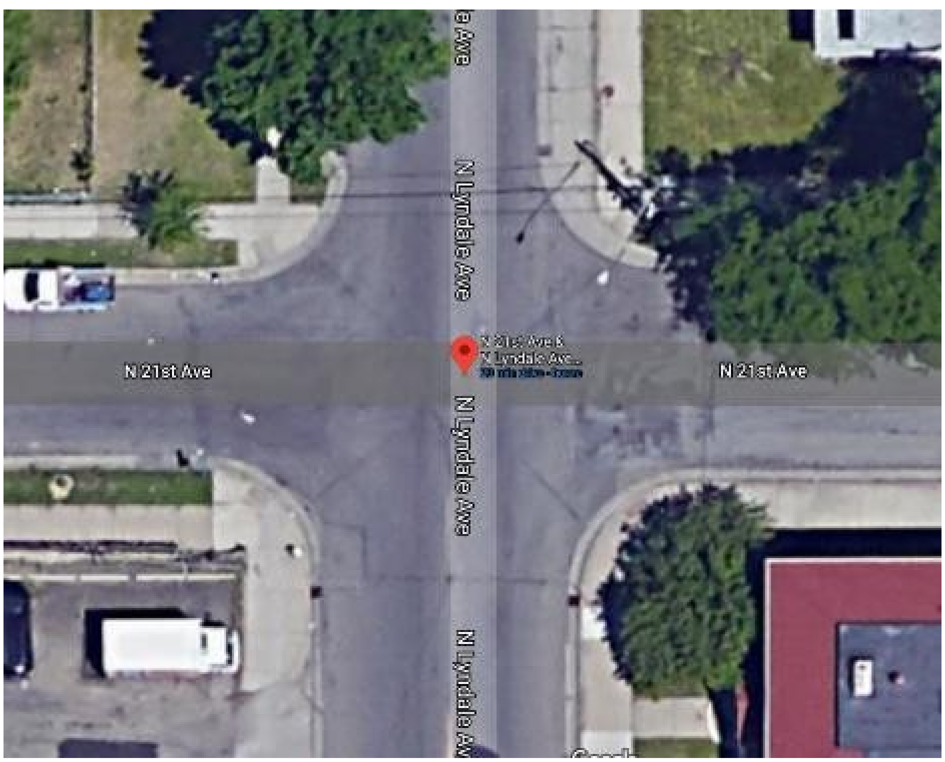
Dowling Ave N. & N Bryant Ave



Lyndale Ave N & 18th Ave N

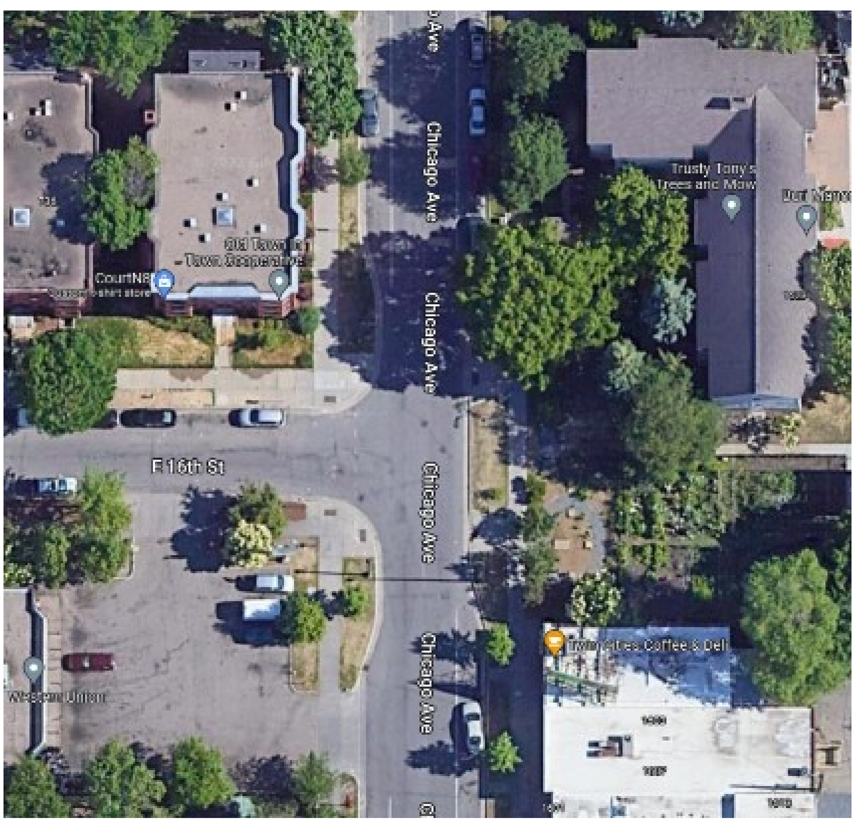


Lyndale Ave N & N 21st Ave



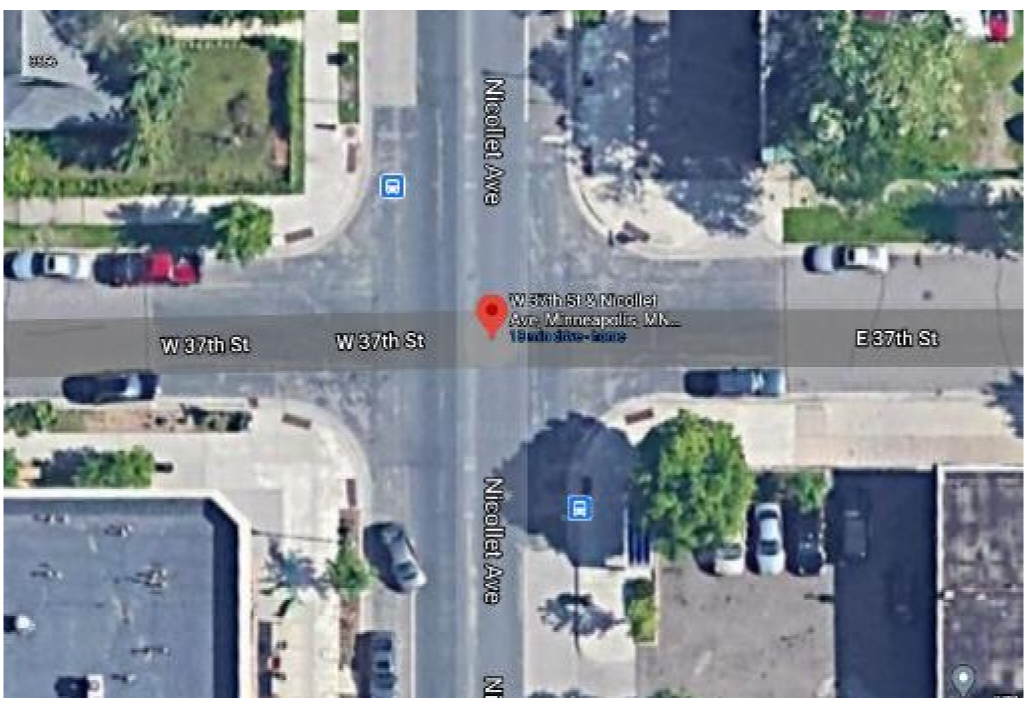
Chicago Ave & S 8th St

Chicago Ave & E 16th St



W 35th St & Nicollet Ave

37th St & Nicollet Ave



Lyndale Ave N & Lowry Ave

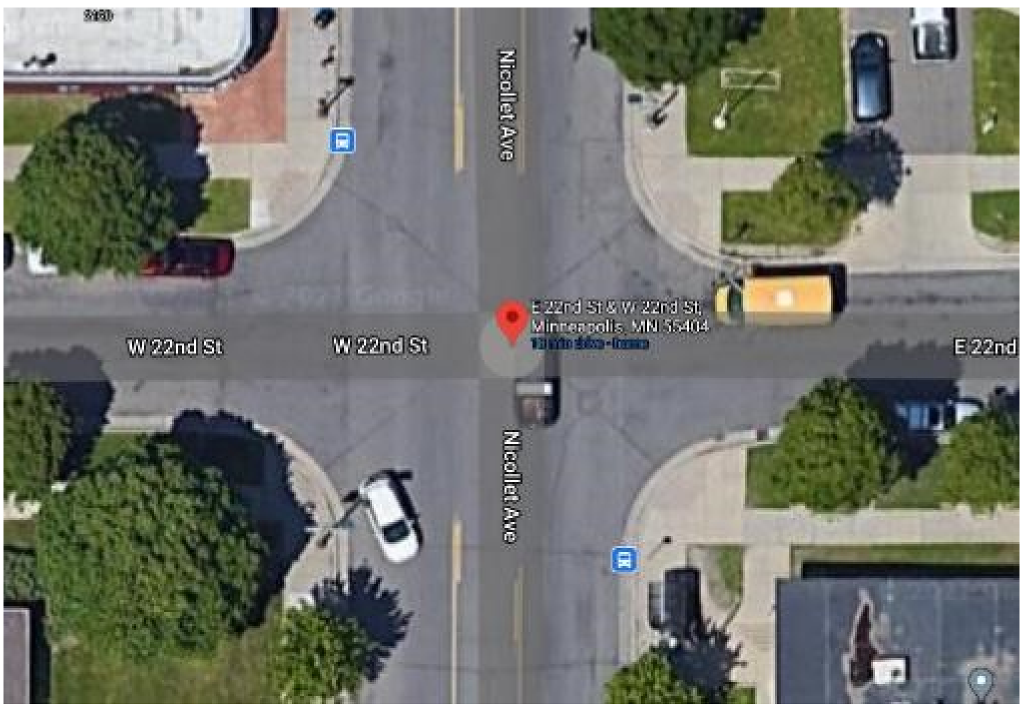
Lyndale Ave & N 33rd Ave

N 2nd St & Lowry Ave

N 2nd St & N 30th Ave

W Franklin Ave & Nicollet Ave

W 22nd St & Nicollet Ave



38th St & Nicollet Ave

39th St & Nicollet Ave

APPENDIX C
PEDESTRIAN SAFETY PROJECT OUTREACH TEMPLATE

Outreach Template (Both)

Hello,

I hope this email finds you well. I'm a part of a transportation safety research group at the University of Minnesota, called HumanFIRST. We’re leading a project with MnDOT and the cities of Minneapolis and Saint Paul to improve pedestrian safety in the Twin Cities. To do this, we will be measuring how drivers react to pedestrians at crosswalks at selected sites in the two cities. In Saint Paul, some of the sites will receive engineering treatments to improve pedestrian safety. In Minneapolis, some of the sites will receive engineering treatments to improve pedestrian safety and other sites will be continuously monitored for comparison. We’re doing this because there have been 2,598 pedestrians injured in motor vehicle crashes in the last five years in the two cities, 234 of these crashes involved children 10 and under.

Outreach Template (St Paul)

Hello,

I hope this email finds you well. I'm a part of a transportation safety research group at the University of Minnesota, called HumanFIRST. We’re leading a project with MnDOT and the cities of Minneapolis and Saint Paul to improve pedestrian safety in the Twin Cities. To do this, we will be measuring how drivers react to pedestrians at crosswalks at selected sites in the two cities. In Saint Paul, some of the sites will receive engineering treatments to improve pedestrian safety. We’re doing this because there have been 840 pedestrian crashes in the last five years in Saint Paul, 75 of these crashes involved children 10 and under.

Outreach Template (Minneapolis)

Hello,

I hope this email finds you well. I'm a part of a transportation safety research group at the University of Minnesota, called HumanFIRST. We’re leading a project with MnDOT and the cities of Minneapolis and Saint Paul to improve pedestrian safety in the Twin Cities. To do this, we will be measuring how drivers react to pedestrians at crosswalks at selected sites in the two cities. In Minneapolis, some of the sites will receive engineering treatments to improve pedestrian safety and other sites will be continuously monitored for comparison. We’re doing this because there have been 1758 pedestrian crashes in the last five years in Minneapolis, 108 of these crashes involved children 10 and under.

To neighborhood

We’re reaching out because one of the crosswalk sites for measuring pedestrian safety is in your neighborhood. We wanted to enlist your aid in spreading the news about this project in your community. Furthermore, we’d like to hear from you and your association about any interest or concerns you may have about the project, and any pedestrian safety issues you have noticed in your neighborhood. Would you be willing to talk with us?

Please contact me at craigc@umn.edu. If you'd like, I can set up a teleconference meeting with your office, myself, and the principal investigator of the project.

Thank you for your time,

Curtis

To city/state safety group

We're reaching out because we know pedestrian safety and transportation safety in general is part of xxxx's mission. We wanted to enlist your aid in spreading the news about this project in your network, as this project will be more effective when more people are aware of it. Furthermore, we'd like to hear from you and your association about any interest, concerns, and feedback you may have about the project. Would you be willing to talk with us?

Please contact me at craigc@umn.edu. If you'd like, I can set up a teleconference meeting with your office, myself, and the principal investigator of the project.

Thank you for your time,

Curtis

To demographic / minority interest

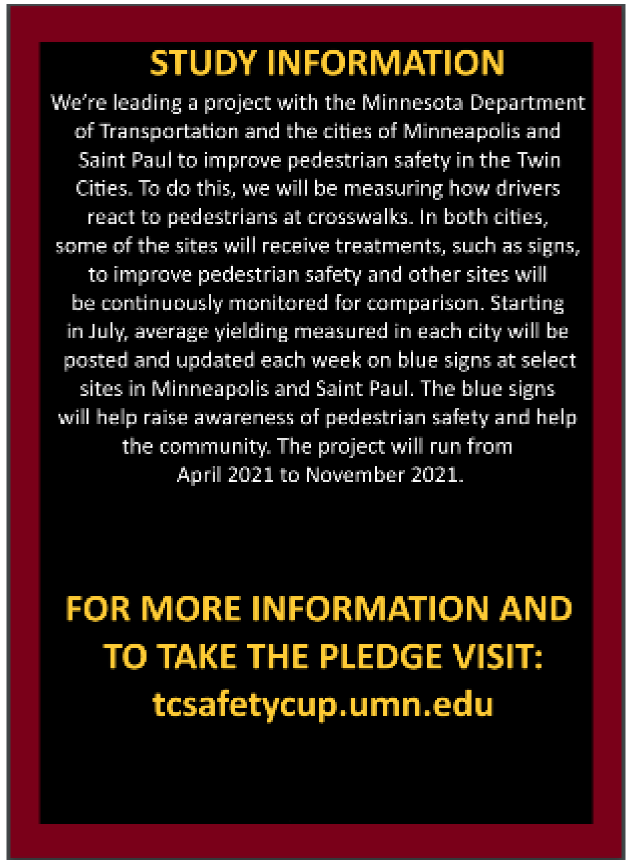
We're reaching out because we have reason to believe that pedestrian safety is important to the xxxx community. We wanted to enlist your aid in spreading the news about this project. Furthermore, we'd like to hear from you any interest or concerns you may have about the project, and any pedestrian safety issues you have noticed for xxxx in the Twin Cities. Would you be willing to talk with us?

Please contact me at craigc@umn.edu. If you'd like, I can set up a teleconference meeting with your office, myself, and the principal investigator of the project.

Thank you for your time,

Curtis

Study and Twin Cities Safety Cup fliers



Twin Cities Safety Cup website

University of Minnesota
Driven to Discover®

One Stop MyU: For Students, Faculty, and Staff

Twin Cities Safety Cup

Project Survey | Take the Pledge! | Pledge Results | Study Information | Study Stats | Twin Cities Safety Stats | Additional Resources

Project Survey

Project Survey

Our laboratory is seeking volunteers to participate in a short survey about pedestrian safety in Minneapolis and Saint Paul. This is a follow up survey to one that was administered in Nov 2020-Jan 2021.

Regardless of your participation in the previous survey, we appreciate your response to this follow up survey. Everyone aged 18 and older is invited to take this survey, including those who previously took it last winter. This survey is expected to take approximately 5 minutes to complete and can be found here: https://umn.qualtrics.com/jfe/form/SV_bIrin9QOLwS1ymy

Stay tuned for survey results in early 2022!

Twin Cities Safety Cup pledge

Twin Cities Safety Pledge

Reaching zero deaths on our roadways takes commitment from all of us, whether we drive, bike, walk, or roll.

Your pledge makes you a partner in our mission, raises awareness of roadway safety issues in the Twin Cities, and helps make sure everyone gets home safely.

I PLEDGE THAT...

As a driver, I will...

- ☐ Expect to see pedestrians everywhere.
- ☐ Be sure to look for and yield to pedestrians when turning at traffic signals
- ☐ Come to a complete stop for people in crosswalks and allow for them to cross
- ☐ Never pass a vehicle stopped at a crosswalk
- ☐ Travel the speed limit (20 mph in Minneapolis and Saint Paul unless otherwise posted)

As a pedestrian, I will...

- ☐ Make my intention to cross clear to drivers
- ☐ Stay alert and not assume drivers will stop for me
- ☐ Cross at crosswalks
- ☐ Make sure a vehicle is clearly coming to a stop before I step out into traffic
- ☐ Obey traffic signals

As a bicyclist, I will...

- ☐ Be predictable by using hand signals
- ☐ Stop for pedestrians at crosswalks
- ☐ Stop at all stop signs and traffic signals
- ☐ Ride in the same direction as traffic and pass with care
- ☐ Use safety equipment including helmets and lights at night

Note: We recognize that not all road users are necessarily drivers, pedestrians, or bicyclists.

We invite you to pledge for all safe behaviors in a commitment to encourage your community to practice safe travel for all modes.

Please provide the following information.

First Name

Last Name

Email

City

- ○ Minneapolis
- ○ Saint Paul
- ○ Other

ZIP code

Optional: Please share a brief statement about why roadway safety is important to you. Note: your quote, first name, and city may be shared on our website (tcsafetycup.umn.edu).

Submit my pledge

APPENDIX D

CODING SHEETS

Unsignalized Coding Sheet

Location: ____________________

Describe condition: Coder #1 Coder #2

Date: Start Time: Stop Time:

	Staged Crossings	Not Yield	Distance Cars Yielded from Crosswalk: Less than 10 ft	Distance Cars Yielded from Crosswalk: Between 10 ft - 40 ft	Distance Cars Yielded from Crosswalk: More than 40 ft	MT Pass	Hard Brake	Billiard Brake	Evade	Trap	Protocol Violation
Staged Pedestrian #1	1										
	2										
	3										
	4										
	5										
	6										
	7										
	8										
	9										
	10										
Staged Pedestrian #2	11										
	12										
	13										
	14										
	15										
	16										
	17										
	18										
	19										
	20										
TOTAL											

	Natural Crossings	Not Yield	Distance Cars Yielded from Crosswalk: Less than 10 ft	Distance Cars Yielded from Crosswalk: Between 10 ft - 40 ft	Distance Cars Yielded from Crosswalk: More than 40 ft	MT Pass	Hard Brake	Billiard Brake	Evade	Trap	Hang Back	Force Yield
Natural Pedestrians	1											
	2											
	3											
	4											
	5											
	6											
	7											
	8											
	9											
	10											
TOTAL												

Instructions

Mark a + beside any crossing number with Cars not Yielding > 10

Mark P for police and SD for Sheriff's Dept.

Signalized Coding Sheet

Location: **Major:** ________________ **Minor:** __________________

Describe condition: _________________ **Coder** ____________

Date: _________________ **Start Time:** **Stop Time:**

	Walk Cycle	Not Look	Look	Not Yield		Yield		Evade	Violation	
		Right	Right	Right	Left	Right	Left		Vehicle	Ped.
First Corner	Major 1									
	Major 2									
	Major 3									
	Major 4									
	Major 5									
TOTAL										
Second Corner	Minor 1									
	Minor 2									
	Minor 3									
	Minor 4									
	Minor 5									
TOTAL										
MISC										

Location: **Major:** ________________ **Minor:** __________________

Describe condition: _________________ **Coder** ____________

Date: _________________ **Start Time:** **Stop Time:**

	Walk Cycle	Not Look	Look	Not Yield		Yield		Evade	Violation	
		Right	Right	Right	Left	Right	Left		Vehicle	Ped.
First Corner	Major 1									
	Major 2									
	Major 3									
	Major 4									
	Major 5									
TOTAL										
Second Corner	Minor 1									
	Minor 2									
	Minor 3									
	Minor 4									
	Minor 5									
TOTAL										
MISC										

Write V for vehicle, P for ped, P for police, when needed.

APPENDIX E
CODING PROTOCOLS

DATA CODER AND OFFICER TRAINING

STAGED PEDESTRIAN AND DATA CODER PROTOCOL TRAINING

Data collection depends on safe and consistent data collection from the research team. A large team of trained research coders was required to collect data at all 32 study sites across Saint Paul and Minneapolis. Training began on April 30th, 2021 and continued as new coders were hired until October 4th, 2021. In total, 15 research staff members were trained to follow the safe crossing protocol and data coder protocol, see Appendix A. Of these staff members, four were full time research staff members, one was a graduate student, and 10 were undergraduate students at the University of Minnesota. Each staff member received four to six hours of coding on the proper crossing and coding protocols. Additional training hours were conducted as needed, depending on coder comfort and confidence, prior to releasing them to standard two-person coding teams. Once training was completed, staff members were allowed to cross/code at any of the 32 study sites.

Training protocols were initially modified to meet additional safety protocols under the University of Minnesota Sunrise Plan, see Appendix E. In summary, these protocols limited the number of staff members that could carpool to study sites, required additional masking inside vehicles, and masking for outside data collection. Undergraduate research coders were provided an additional letter of permission, written by the study PI, to work in the field under the Sunrise Plan. These protocols were followed from April 30th, 2021 until July 1st, 2021. Following this date, the research team adhered to CDC guidance for masking and social distancing based on location, number of individuals present, and vaccination status.

OFFICER TRAINING

Officer training with the Saint Paul Police Department did not occur as planned. The request by MnDOT to remove enforcement as a study component resulted in this activity being unnecessary. The research team has redirected this effort to engage in additional outreach with neighborhood associations and plans to lead two workshops in the month of October to educate stakeholders on how to collect data on demonstration projects in the future.

SAFE CROSSING PROTOCOL AND DATA COLLECTION PROTOCOL

HumanFIRST Laboratory
SAFE CROSSING PROTOCOL

Introduction

Pedestrian safety is important for livable communities and relies on the cooperation of drivers to look for and legally stop for pedestrians at crosswalks. This study will measure driver yielding rates in the cities of Saint Paul and Minneapolis, MN through the use of staged crossings. The safety of the research team is of the utmost importance. Following this protocol is the best way to ensure that our team remains safe and our data quality meets the highest standards.

Staffing Requirements

- Research coding teams must consist of two trained coders who will both alternatively serve as either the staged pedestrian or the recorders. The staged pedestrian will initiate the yield request to on-coming vehicles and cross the street once vehicles yield and the recorder will code the driver behaviors on the coding sheet. Whenever possible, coders will observe natural pedestrian crossings and record driver behaviors on the coding sheet.
- Both team members should wear solid, weather appropriate clothing (no visible patterns or logos) with jeans and comfortable shoes with little-to-no retroreflective clothing. Additionally, team members will carry project information handouts to provide pedestrians.
- Each member should have a clipboard holding safety protocol and multiple coding sheets and a pencil to take notes and easily correct entry errors. The Safe Crossing Protocol should be taped to the back of the clipboard to easily reference and read aloud.
- Team members must be junior or senior undergraduate students studying in a related field/discipline (e.g., engineering, psychology, urban studies) or professional research staff and who have received a minimum of 3 hours of in-person training of the procedures.
- Ensure all COVID 19 safety regulations are met in accordance with CDC recommendations and the sunrise plan. General requirements include wearing at least one mask while on site, and whenever possible maintaining social distancing.

Coding Session Requirements

- Coding sessions should occur only under clear weather conditions (i.e., not during rain, snow, or icy/wet surface conditions) and during daylight hours (i.e., not during dawn, dusk, or dark conditions).
- Coding sessions should occur between the hours of 8:00 am and 4:30pm. In order to ensure pedestrian traffic is present, coding at signalized intersections should occurring during rush hour (8:00am to 8:30am and 4:00pm to 4:30pm). Coding at unsignalized intersections should occur outside of rush hour times (8:30am to 4:00pm). Coding sessions should be approved or assigned by supervisors.
- Pavement markings should be visible from recorder coding position. Markings will be spray painted by supervisors at each site prior to data collection. Notify supervisors if markings are no longer fully visible so that they can be re-touched. Markings should be on the curbside to mark "dilemma zone" for both directions of traffic and in-street to mark 10 and 40 feet yielding distances.

General Instructions

- The team member first serving as staged pedestrian will read the ***Safe Crossing Protocol*** aloud to the recorder then proceed with 10 staged crossings.
- The second team member will then assume the role of staged pedestrian by first reading the ***Safe Crossing Protocol*** aloud to the newly assigned recorder before proceeding with the final 10 staged crossings.
- Recorders will follow ***Coding Instructions*** as they observe the staged and natural (*if applicable*) pedestrian crossing
- The coding team will step back to observe and score the vehicle behavior in the presence of any natural pedestrians who initiate a yielding request (i.e., step off or near the edge of the curb) in the presence of oncoming traffic. Each code-able natural pedestrian crossings will take the place of a planned staged crossing.

Safe Crossing Instructions

All crossing should follow the standard safe crossing protocol. The safety crossing protocol involves the following procedure:

Step 1: Place one foot into the crosswalk, and do not take additional steps until a vehicle yields or a sufficient gap presents itself.

Place one foot when the car is just beyond the marked "dilemma" zone. If there is street parking, you will need to step out to the edge of parked cars if cars are parked close to the crosswalk.

Step 2: If the vehicle makes no attempt to stop, do not proceed to cross.

If the vehicle is traveling at excessive speeds or is traveling close to the curb face or parking lane, step back as the vehicle approaches.

Step 3: If the vehicle clearly begins to yield and the next lane is free, begin lane crossing.

Wave to the first yielding vehicle to give indication of your intention to cross and thank them for stopping. **NOTE: If you see a vehicle rapidly approaching the stopped vehicle in the same lane ensure it comes to a safe stop before proceeding into the lane of the stopped vehicle.**

Step 4: On multilane roads, **always stop at the lane line, make sure the next lane is clear.**

This step is essential to prevent the possibility of being involved in a Multiple Threat crash. **Looking is not enough because you have a limited reaction time and if crossing at a normal speed, you will not be able to react in time unless you stop. Get into the habit of making a brief stop even if the car yields further back.**

Step 5: If the vehicle yields in the next lane of multilane roads, wave to the vehicle and proceed to the centerline or median.

Step 6: At four lane roads with a median or pedestrian refuge island treat the second half of the crossing the same as the first half.

That is place, a foot in the crosswalk and wait for any oncoming cars to yield before entering the lane. At four lane roads without a median or pedestrian refuge island, stop at the lane edge and wait for any oncoming traffic to yield before crossing the centerline.

Step 7: <u>If a large gap appears in traffic, proceed through the crosswalk and do not wait.</u>

Safe Crossing Abbreviated Protocol

This protocol should be read aloud before each staff member serves as the staged pedestrian for each coding section (i.e., 10 staged crossings).

- Always stay alert and be aware of traffic from all sides and all lanes.
- Follow the Safety Crossing Instructions closely.
- Always ensure that the oncoming vehicle is clearly yielding or stops before proceeding.
- Make eye contact and signal to the driver that you intend to cross in front of them.
- Do not put yourself in an unsafe situation. If a vehicle is traveling too fast or too close, step back to a safe position.
- On multi-lane roads, always stop at the lane line, search and make sure the next lane is clear.
- Above all, do not attempt to cross if it cannot be done safely!

Unsignalized Crosswalk Coding Instructions ****Use for both staged and natural pedestrian crossings***

Step 1: Place yourself according to your training in a position away from the crosswalk, as to not give false indication of an intention to cross, but where you are able to view the movements of the staged pedestrian and "dilemma zone" markings for both direction of travel. You should be able to see in-street markings from this position as well.

Step 2: Observe vehicles approaching from the lanes of travel on the pedestrian's side of the street.

- Any vehicle approaching which is on the <u>outside</u> of the "dilemma zone" marking once the staged pedestrian steps off the curb should be coded. If the vehicle makes no attempt to stop, score it as "**Cars Not Yielding**". Any subsequent vehicles which do not stop should also be scored as "**Cars Not Yielding**".
- Any vehicles that are <u>inside</u> the "dilemma zone" when the pedestrian steps off the curb should not be scored if they do not stop, but can be scored if they chose to yield (see Step 3). Code police as "**P**"

Step 3: Once a vehicle stops at the crosswalk, score them as "yielding" in one of the *Distance Cars Yielded* from Crosswalk bins:

- If no in-street dots are visible (i.e., they are stopped very close to the crosswalk), score them in the "**Less than 10ft**" yielding bin.
- If one in-street dot is visible (i.e., stopped slightly further back from the crosswalk), score them in the "**10-40ft**" yielding bin.

- If two in-street dots are visible (i.e., stopped at a distance back from the crosswalk), score them in the "**More than 40ft**" yielding bin.

Step 4: On multilane roads, if a vehicle yields in one lane and other vehicles in the same direction of travel do not stop, score them as "**Cars Not Yielding**" <u>and</u> make note of each one in the " **MT Pass**" bin under the Multiple Threat Conflicts.

Step 5: If one of the vehicle brakes hard (e.g., audible tires screech or visible downward vehicle nose), score it as "**Hard Brake**" under the Multiple Threat Conflicts section.

Step 6: Following a "**Hard Brake**", if another subsequent vehicle behind the original hard brake is forced to brake hard, score this occurrence as a "**Billiard Brake**".

Step 7: Score vehicles in the opposing lane of travel in the same manner as the first direction. Begin scoring vehicles outside of "dilemma zone" once the pedestrian has either been yielded to in all lanes in the first direction of the roadway or has a large gap and is proceeding to walk across the opposite lanes of travel. If the vehicles in the opposite lane of travel do not yield so that the pedestrian is forced to stand on the centerline with vehicles moving in both lanes of travel, code this event as a "**Trap**"

Step 8: If the pedestrian (most likely natural ped) must move themselves out of harm's way to avoid a vehicle (e.g., step back out of the road, or move quickly forward to avoid the vehicle), then code it as an "**Evade: P**", if a vehicle must quickly swerve to avoid the pedestrian or another yielding vehicle, then code it as an "**Evade: V**". Natural pedestrians should also be noted if they "**Force the Yield**" by stepping into traffic before a driver is clearly yielding or if they "**Hang Back**" by standing near crosswalk entry but not making their intention to cross clear by placing one foot off of the curb.

Step 9: Importantly, you serve as a second set of eyes to help keep your partner safe. If the staged pedestrian fails to follow protocol (e.g., does not stop at lane's edge or check for Multiple Threat Conflicts), code the crossing under "**Protocol Violation**". Give real-time feedback to your partner and review protocol with them. Alert supervisors for any safety concerns you have about safety training of you or your partners or of specific crosswalks.

<u>Signalized Crosswalk Coding Instructions</u>

Step 1: The coding team will be split into two where one coder (Coder 1) will stand at a corner where vehicles will be turning from the major roadway to the minor roadway. The other coder (Coder 2) will stand at the opposite corner of the intersection to code. Each coder will then fill out the general coding data at the top of the signalized coding sheet for that intersection.

Step 2: When the walk signal begins across the major walkways, both coders will observe the driver of the nearest right-turning vehicle, monitoring whether they look for pedestrians to their right. The coders will code whether each driver "**Look**", or "**No Look**". When a vehicle in the near lane is turning in the presence of a pedestrian, coders will not code the looking behavior of the driver but will code the yielding behavior to the pedestrian as outlined in Step 3.

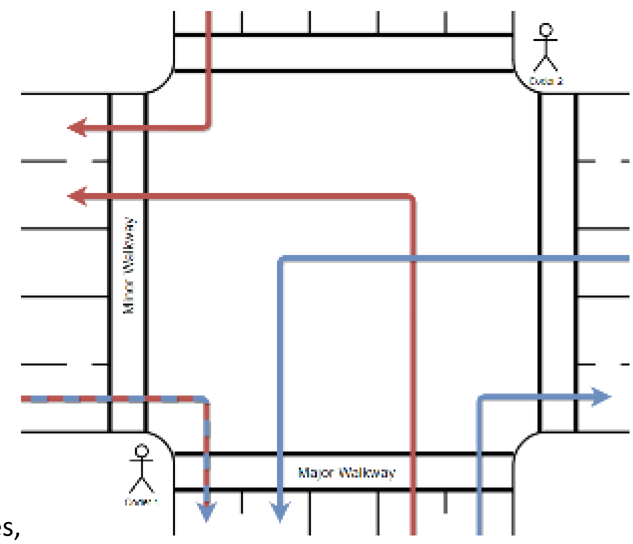
Step 3: During the crosswalk cycle, each coder will monitor any turning vehicles that are crossing a crosswalk near the presence of a pedestrian. These occurrences will be coded as “**Yield**”, or “**No Yield**” depending on whether the driver of the vehicle yields to the pedestrian walking in the crosswalk.

Step 4: During the walk cycles coders should also mark whether and pedestrian or vehicle evading occurs. These occurrences are tallied in the **“Evade**” columns of the coding sheet and are labeled as a “**P**” for pedestrian evasion and a “**V”** for vehicular evasion.

Step 5: Finally, each coder should note the presence, if any, of unsafe pedestrian crossings or violations. Coder will tally these occurrences as monitored under either the vehicle or pedestrian columns labeled “**Unsafe Crossing or Violation**”

- Unsafe crossings include pedestrians in the crosswalk before or after the walk signal
- Violations may include vehicles turning right on red when instructed otherwise or any deviation from the stop lights

Step 6: Each coder will complete steps 2 through 5 at the major crosswalk through 5 complete cycles of the stop light.



Step 7: Upon completion of 5 crosswalk cycles, both coders will move to alternate corners of the intersection to conduct coding for 5 crosswalk cycles at the minor crosswalks of the intersection.

Step 8: Upon coding completion for 5 crosswalk cycles at both the major crosswalk and minor crosswalk, each coder will note the time as the stop time for coding and proceed to further coding.

Pre-Data Collection Preparation

Name: ______________________ Completion Date: ______________________

- Complete Sunrise Plan (see return to work forum presentation)
    - Complete ME COVID Safety Checklist (Due Tuesdays at midnight)
    - Receive Safety Checklist receipt/approval
    - Add yourself to HumanFIRST ME Checklist
    - Submit UMN Sunrise Form
    - Forward Dean approval to Nichole Morris/Curtis Craig/Brad Drahos
- Review study Safe Crossing Protocol and review testing site locations

Day of Data Collection Preparation

Start Time: ______________________ Date: ______________________

- Bring all necessary equipment/supplies
    - Mask(s)
    - Hand sanitizer
    - Clorox wipes
    - Clipboard (1 per team)
    - Pencil and eraser
    - Water
    - Sunscreen (if necessary)
    - Project info/handouts
    - Data sheets and protocol

Post Data Collection Preparation

Time Completed: ______________________

- Update data collection database
    - Transfer written data collection to electronic copy
    - Send electronic copy of data to Nichole Morris/Curtis Craig/Brad Drahos
- Notify team of any issues/concerns
- Notify team if markings need repainting.

University of Minnesota Sunrise Protocol

Instructions:

We expect that PI's will be required to provide information that describes the reasons for reopening and plans for assuring a safe lab environment. We expect that the required information will be modeled after the current requirements for opening labs that have COVID 19 exceptions.

The guidelines presented herein are intended to assist in preparing the required documentation for reopening labs. We expect "Summary information" will be required (section I of this document) as well as a "Partial, reduced operations, lab plan" (section II).

Note: this guidance does not supersede any guidelines from the dean's office or University. This document is based on the current requirements for opening labs that have COVID 19 exceptions.

SECTION I

SUMMARY INFORMATION FOR LAB REOPENING

1. Justification

- The pedestrian safety project requires on site data collection at a total of 18 intersections across the twin cities. Data collection will require two coders at a given site to monitor pedestrian and driver activity throughout the summer. The data collection is necessary for project progress in order to analyze the effectiveness of pedestrian safety awareness and engineering changes to intersections. This data collection was slated to occur late last year, but was delayed due to COVID 19; however, any further delays would put the project in jeopardy in its current state.

2. Description of Research and Precautions for Health and Safety

1. Provide a brief paragraph summary of the research / outreach necessary and specifically why it fits the justification selected.

The research team must collect field data to support a research contract and its timeline. The data collection involves observing driver behavior at select locations in Minneapolis and Saint Paul. The methods to collect this data require two researchers to be present. The first must cross the street in a safe and controlled manner, known as staged crossing, to expedite the pace of observations of driver-pedestrian conflicts (i.e., pedestrian wishes to cross the street at the same time a driver is approaching the crosswalk). The second must stand back and observe the driver behaviors and code them for analysis. Data collection at each site must occur at least once a week. The data collection was set to begin last fall, but the PI worked with the sponsor to delay to this spring. Further delays are not possible without a no-cost extension that the research lab could not withstand financially.

2. How will this proposed exception be executed in compliance with the Governor's stay-at-home executive order?
https://mn.gov/governor/covid-19/faq/
Beginning April 15, the requirement to work from home shifts to a strong recommendation. Employers are also strongly encouraged to implement reasonable accommodations for at-risk employees, or employees with one or more members of their household who have underlying medical conditions and are not yet eligible for vaccination.

The proposed testing plan will not include any at-risk employees given the physical nature of the work. Should any employees become at risk or have an unvaccinated family member at home that are put at risk by this work, they will be reassigned to other research duties from their home.

3. Describe precautions you will take to ensure health and safety (methods and means for social distancing, PPE, etc.) Consider whether or not your PPE supplies have already been redirected for healthcare use, or if your on-hand quantities are sufficient given the inability to procure many forms of PPE for non-healthcare use.

The research team will complete all data collection outside, will wear masks, and maintain 6 ft distance between them. When possible (i.e., access to personal transportation) they will travel separately to study locations. When necessary, coders may travel in cars together. The protocol for traveling in cars together to study sites will be that they must roll the windows down, wear two layers of masks, and the passenger should sit in the passenger side back seat.

The team will self-screen for any symptoms prior to arrival. There is flexibility in rescheduling or reassigning coding sessions so that staff should not feel any time pressure to attend should any symptoms be present. The PI will provide surgical grade mask; however, staff may substitute for their own cloth mask or double-mask as they feel appropriate (especially given their travel accommodations). The PI will also provide Clorox wipes and travel size hand sanitizer to each team member to sanitize their hands as needed.

Safety precautions will be modified if new guidance is issued by the CDC.

3. Detailed lab plan (see template provided in Section II) is not applicable and has been modified

General considerations in developing a lab plan for reopening

- Limit the number of people in a given room based on sufficient spacing/distancing between people/work stations. Consider access to lab entrance.
- Consider pre-scheduling and possibly "platooning" or "split shifts" to reduce the number of people present.
- Require that appropriate protective gear, such as gloves and N95 masks, be available and employed for situations where laboratory operations require close interactions between people, or where PPE is required for the research work itself.
- Create disinfection protocols for labs and offices (wipe down of surfaces before/after each user with appropriate bleach, alcohol, or other approved disinfectants).
- Outline a "buddy system" to ensure that anyone alone in a lab is in regular contact with another individual who can provide/call help in an emergency.
- All meetings, lab meetings, etc., would be expected to remain online, at least for the short term
- Limit training new individuals in lab operations.

We are NOT requesting access to any labs on campus. Our researchers are working remotely from their home for other tasks related to this project.

The safety list in the COVID-19 website is designed for laboratories. We have developed our own check list of what we will do to protect ourselves during the coding sessions.

SECTION II

Field Data Collection
Date: April 15, 2021-Sept 30, 2021

Location: Saint Paul and Minneapolis Crosswalks (selected)
Responsible PI: Nichole Morris - **Contact** 316 – 648 – 4128 (mobile phone)
Other lab group emergency contacts:
Curtis Craig 214-223-2045
Bradley Drahos 763 – 657 – 6012

DEHS Emergency Contact:
Anna Sitek, englo131@umn.edu, 612-625-8925

1) Working remotely
Any research tasks that does not require physical presence in the lab space will still be done remotely. This includes - literature survey, writing activities, logging lab notebook entries, computer aided design and prototyping, lab meetings and brainstorming discussion etc. While we will do our utmost best to reduce the risk of infection, it is possible that you are exposed to SARS-CoV-2 in the course of this field work. You should be aware of this risk and participation in this research activity is voluntary. If you feel uncomfortable to participate in this field work while the SARS-CoV-2 situation is not yet under control, please let me know and I will arrange alternative research tasks to the best of my ability.

2) Lab reopening from hibernation: DOES NOT APPLY

3) Working in lab space: DOES NOT APPLY
In addition to mandating remote working, we will implement three procedures to ensure safe working environment during coding duties.

3.1. Reducing the number of people simultaneously present at data collection sites.
To ensure proper social distancing we will ensure that the number of people who are simultaneously present at any point of time is limited to 2 people during normal data collection and 4 during training sessions. There should be no more than 2 people in any vehicle (i.e., 1 driver and 1 passenger) that travels to a data collection site and all those present must adhere to social distancing.

3.2. Time scheduling

Coding sessions (both day and time) will be assigned to you and this schedule will repeat each week until Sept 30th, 2021. You will be scheduled for each data collection session with another coder. Apart from training sessions, there will be no other coders present.

3.3 Limiting use of shared equipment and facilities
When necessary, coders may travel in cars together. The protocol for traveling in cars together at study sites will be that they must roll the windows down, wear two layers of masks, and the passenger should sit in the passenger side back seat.

Data collection equipment, such as clipboards or electronic logging devices, may be shared by two coders. Shared equipment should be wiped down with Clorox Wipes at the start of each testing session. Coders must sanitize their hands prior to handling any data collection equipment and should sanitize their hands after handling the equipment.

4) Lab sanitation, personal protective equipment, general safety:

4.1 Washing hands: Wash hands prior to arriving at coding sites and wash hands once coding is completed (once facilities are available).

4.2 Periodic decontamination of high-touch surfaces in training: High-touch surfaces should wiped with Clorox wipes at the start and end of each session.

4.3. PPE (lab use): You will be required to wear a mask during coding and two masks when sharing a vehicle. The lab PI will provide you with a disposable surgical mask for your first layer and you should apply your own mask as a second layer if you are riding in a vehicle with another coder. You may substitute the surgical mask for your single mask use with your own cloth mask if that is more comfortable or convenient for you. The PI will also provide hand sanitizer and Clorox wipes to support safe hand-off of shared equipment during coding sessions.

4.4. Gas Cylinders: **DOES NOT APPLY**

4.5 Other Field Trip Specific Safety Measures: The researchers will take their temperature before and upon returning from coding sessions. If temperatures are above 100.4° F, the researcher will not leave home and will contact their primary medical provider. The researcher should also not leave home if any new or unexpected symptom occur including but not limited to:

- Fever or feeling feverish (chills, sweating)
- New cough
- Difficulty breathing
- Sore throat
- Muscle aches or body aches
- Vomiting or diarrhea
- New loss of taste or smell

5) Individual project plans

Given individual circumstances, I will work with each of you to develop individual working plans for the reopening of the lab.

6) Meetings:

To ensure that you are performing all coding, crossing, and safety protocols correctly, you will complete 2 hours of in person training with the study PI or Co-I. Up to 2 other coders may be present at these outdoor training sessions. All other meetings will be conducted remotely on zoom.

7) Looking out for each other

7.1 Buddy system: You should help monitor and alert your fellow research staff members if you notice that their mask is not properly worn, a surface has not been cleaned or they otherwise are not complying with safe protocols.
7.2. Symptoms: If you are experiencing any COVID-19 symptoms (as listed at the cdc website: https://www.cdc.gov/coronavirus/2019-ncov/symptoms-testing/symptoms.html), you will be required to self-isolate.

7.3 Reporting potential exposure to COVID -19: The effect of COV2-SARS on each individual is not yet clear. In the event that you become aware of potential exposure to COVID-19, please report this to Boynton and me, and self-isolate for 14 days. We may have to provide information to department officials and medical health professional as well. Boynton Health is offering telehealth services during this time for physical ailments and consultation for potential exposure to COVID-19. Call 612-625-3222 to schedule a telehealth appointment. Additional information regarding privacy of health data, as related to COVID19, can be found at this link (https://humanresources.umn.edu/sites/humanresources.umn.edu/files/communication_to_supervisors_regarding_ensuring_employees_health_privacy.pdf)

7.4. Mental health resources: This is a unique situation unlike any we have faced. Many of us are from outside Minnesota and do not extensive family and social support networks. Being self-isolated/ working remotely can be stressful and result in anxiety. Boynton Health is offering telehealth counseling and psychiatric care (call 612-624-1444 for more information). If you need immediate assistance, the crisis lines are open 24 hours a day at 612-301-4673 or text "UMN" to 61222. Help link: http://mentalhealth.umn.edu/index.html

Other links for the Twin Cities campus include:

- International Student & Scholar Services counselors, call (612) 626-7100 to make an appointment.
- Student Counseling Services
- Boynton Mental Health Clinic
- Boynton Health
- Office of Student Affairs Care Program
- Let's Talk (informal drop-in consultations with a counselor)
- Bias Response Referral Network (BRRN)

7.5. Medical resources: For non-emergencies, contact Boynton Health Services (612) 625-8400. Contact 911 in an emergency.

8) Reporting/ discussing issues with this arrangement
Graduate students: Director of Graduate Studies
Post docs, researchers and visitors: Chief of Staff, Kerri Miller

The following guidance is offered by the university if you are concerned about a possible violation of law or policy (https://research.umn.edu/units/spa/proposals/policies-compliance/employee-whistleblower-protection). You may first consider raising it within CSE or the ME department. The University also offers a confidential reporting service called Ureport. Access Ureport through their website or by calling 866-294-8680.

9) Reporting unsafe social distancing practices by personnel

Getting back to research is a privilege that will be taken away if any personnel is putting people's health at risk. If you observe unsafe behavior you should report it.

Within lab space: Report to PI

Within department: report to Chief of Staff, Kerri Miller

Lab Reentry Checklist These are NOT applicable to field testing

☐ Remove any posted hibernation notifications

☐ Flush your eyewash for 10 minutes to ensure that the lines are clear

☐ Clean and disinfect lab benches. Be sure to make fresh disinfection solutions.

☐ Is the room free of odors? Flush cup sinks to reduce odors from dry traps.

☐ Check for signs of utility failure (e.g. power outage, etc.)

☐ Check refrigerators and freezers to see if they are working properly. Odors may build up during an extended hibernation.

☐ Check room and local ventilation. You can perform a qualitative check by using a tissue/kimwipe to see if your fume hood or local exhaust are working.

☐ Check any running equipment for damage or power failure (e.g. pumps, glove boxes, anaerobic chambers, etc.). Check that all systems left under an atmosphere of inert gas are still inert.

☐ Inspect the integrity of all tubing for gas/water to make sure they are free from leaks

☐ Check integrity of chemical containers on shelves and in cabinets. Clean any residue seen on the outside of the bottle and check the quality of chemicals if the container integrity has been compromised. Dispose of any chemicals that are expired or where the quality is suspect.

☐ Test peroxide forming chemicals that are open prior to re-use.

☐ If working with radioactive materials, complete a post-hibernation radiation survey. Then notify Radiation Safety, who will help reconcile your reports.

APPENDIX F

LOOKING RESULTS

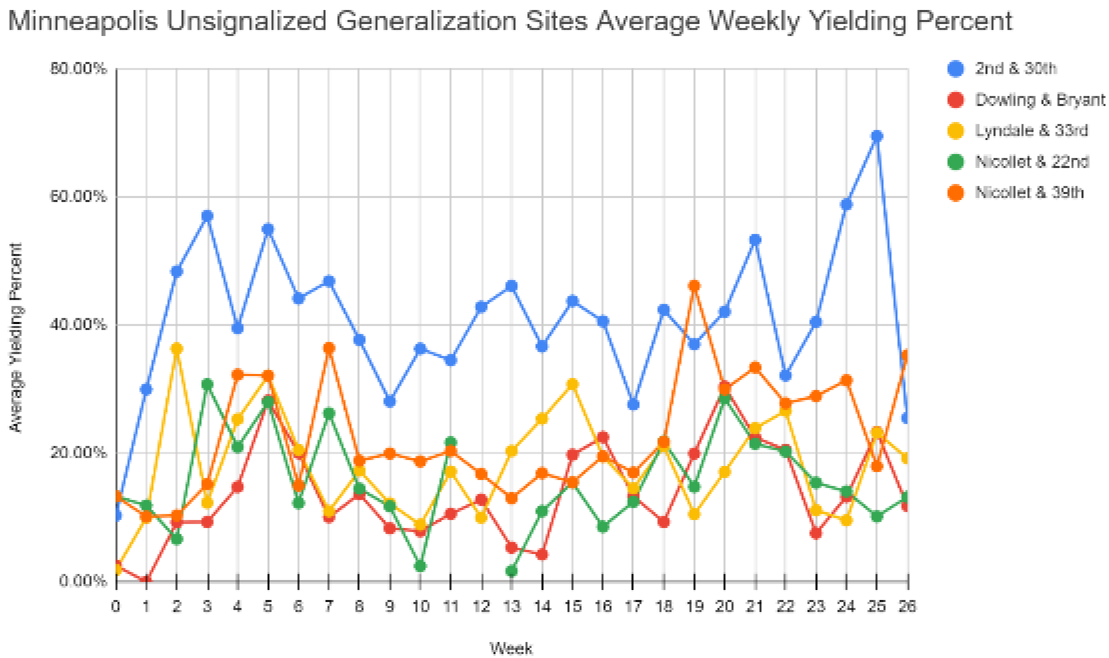


Figure 1. Weekly average for yielding at Minneapolis unsignalized generalization locations.

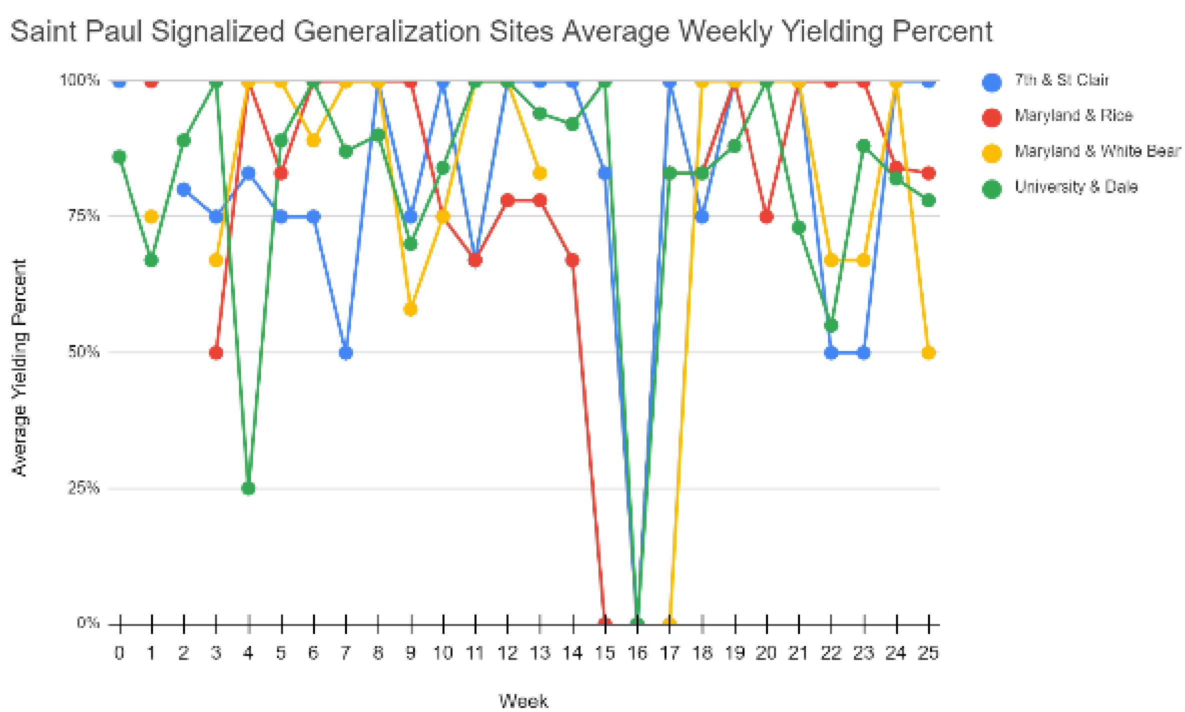


Figure 2. Weekly average for yielding at Saint Paul signalized generalization locations.

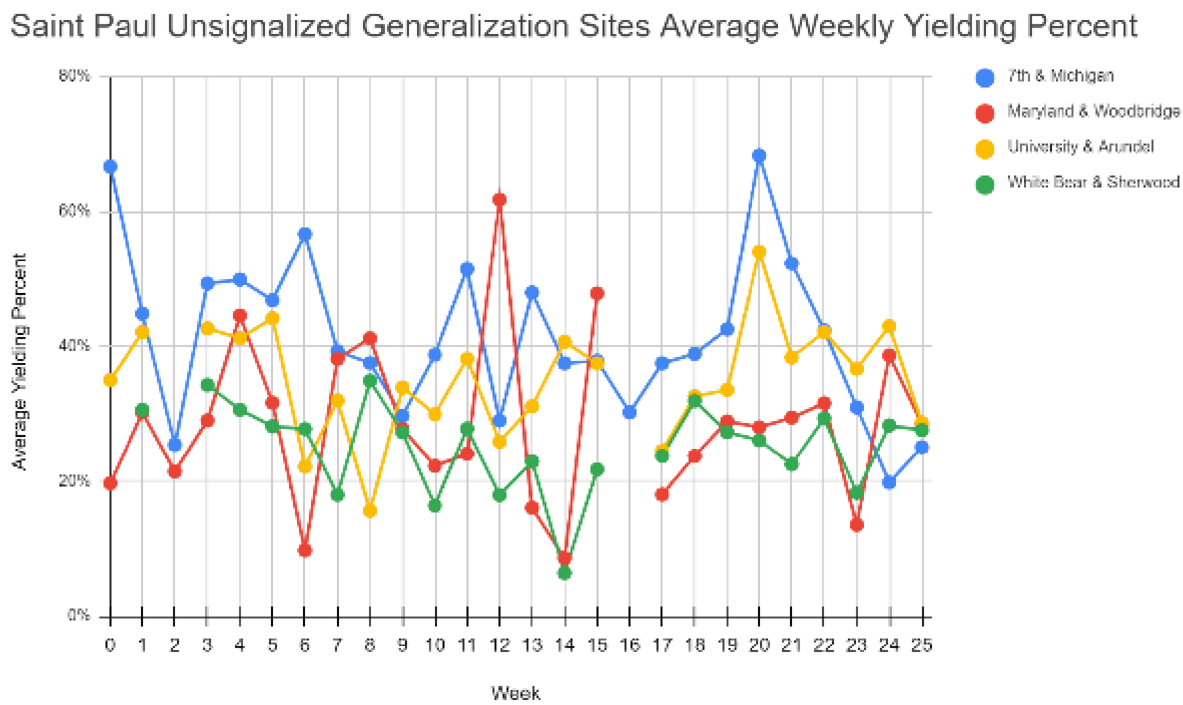


Figure 3. Weekly average for yielding at Saint Paul unsignalized generalization locations.

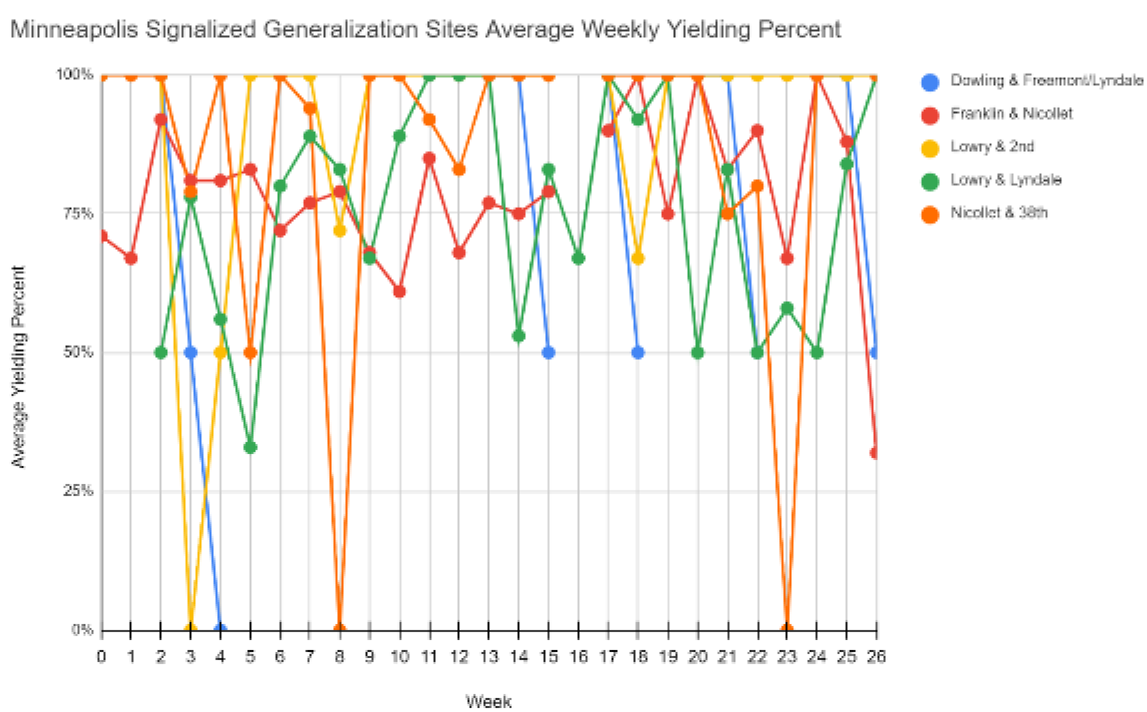


Figure 4. Weekly average for yielding at Minneapolis signalized generalization locations.

Average Looking at Signalized Locations

Weekly looking for pedestrians before turning averages by site are displayed in the following Figures 16 through 22 for signalized sites.

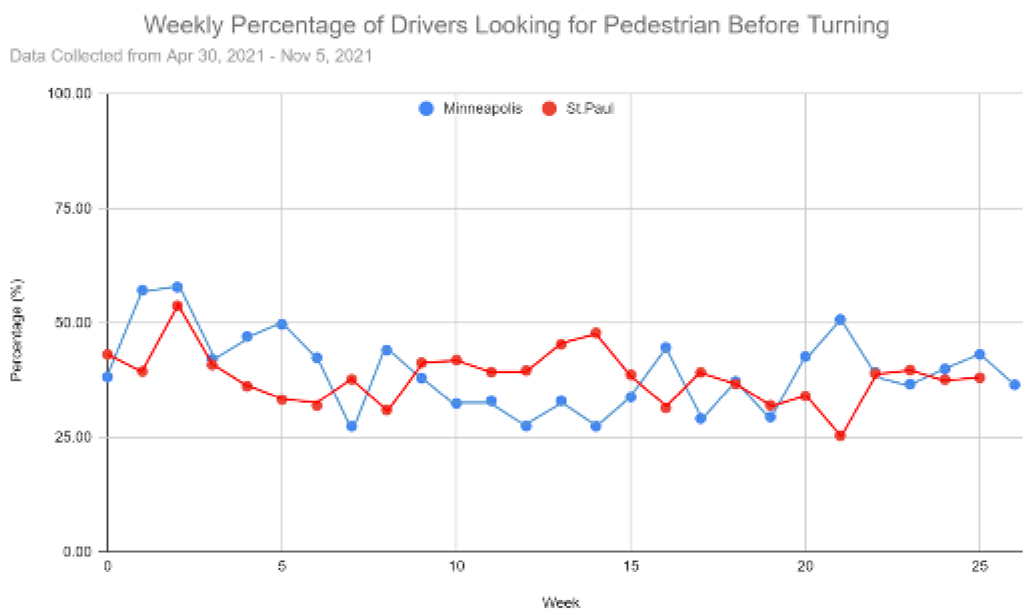


Figure 5. Weekly average looking for pedestrians at signalized locations across two cities.

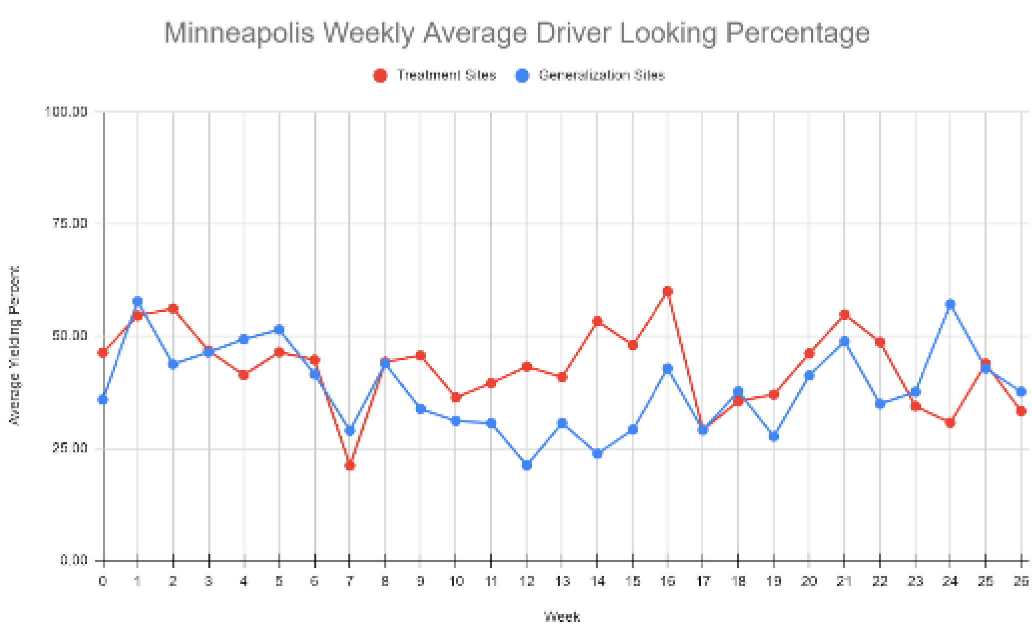


Figure 6. Weekly average looking for pedestrians at Minneapolis signalized locations by treatment type.

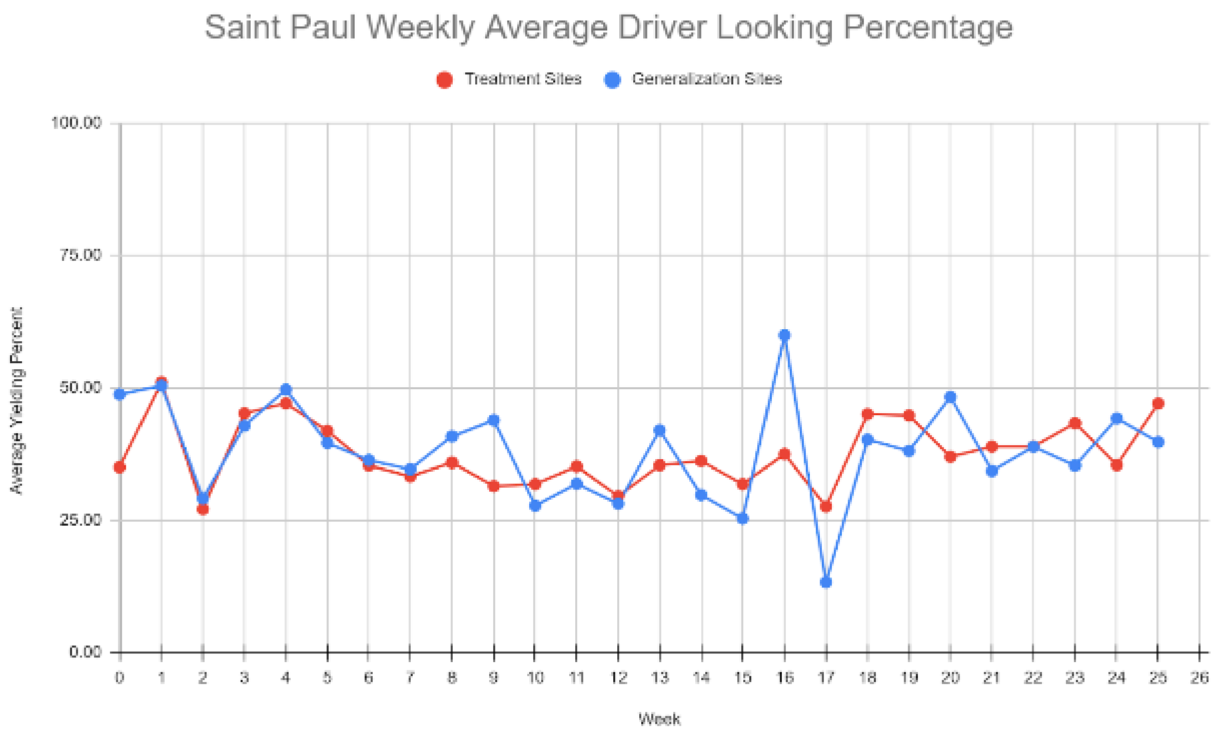


Figure 7. Weekly average looking for pedestrians at Saint Paul signalized locations by treatment type.