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Implications of Modifying State Aid Standards: Urban Construction or Reconstruction to Accommodate Various Roadway Users

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16. Abstract (Limit: 250 words)

The degree of modal split in the United States has continued to change with increased use of non-motorized modes. To accommodate a variety of users, context-sensitive solutions are being pursued. Such solutions call for the sharing of right-of-way by multiple user groups with different and often competing demands. Traditionally, the needs of vehicular traffic have been prioritized as evident in many current design standards. This research focuses on developing guidance for design decisions to best balance the competing needs and accommodate all expected roadway users. Non-standard design solutions, often associated with complete streets, were investigated in two major contexts. The first involved a comprehensive review of the current-state-of-the-practice in design standards, complete streets, and associated legislation in Minnesota and nationally. Second, a detailed analysis of 11 'complete street' study sites was conducted. The study primarily focused on evaluating changes in safety and operations between the periods before and after implementation. Differences in the characteristics of the study sites and varying degrees of changes and improvements conducted at each site prevented an aggregate quantification of the implications of complete street improvements across all sites, and specific recommendations for changes in design standards. Nevertheless, the analysis of complete street designs implemented at the 11 study sites suggest that changes made to these study sites did not result in adverse safety or operational impacts. Therefore, providing flexibility and modification to the State Aid Design Standards in the context of complete streets and conditions specified in this research appears to be a reasonable consideration.

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Final Report

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Executive Summary

As the use of non-motorized modes of transportation increase in the United States, the degree of modal split in traffic continues to change. Facilities can no longer be expanded to provide increased capacity for motorists at the expense of other modes and road users, a common practice in recent years. Therefore, context sensitive solutions are being pursued to accommodate a variety of road users. Possible motivation for these solutions may have come from legislation, changes in funding, new schools of thought on transportation and the environment, and/or a variety of other reasons. Regardless of the motivating factor(s), roadway designs that provide safe and efficient mobility for modes other than the vehicles are becoming more desirable.

The use of roadway facilities by multiple modes often requires user groups to share space within the fixed width of the roadway cross-section. Space sharing can be complicated by the fact that different user groups have different needs, which can impact the safety and operations of the roadway. Accommodating these different needs may necessitate the reconsideration of long held roadway design standards. As travel lane widths were increased to improve the capacity and safety of a roadway in the past, perhaps it is now possible to reduce travel lane width and allocate this space to shared or separate use by other modes. This 'complete street' concept, or reasonably providing safe and efficient accessibility to all roadway users, requires reconsideration of these long held design guidelines and standards. A question remains as to the impact of changes and modifications to design standards in an effort to accommodate the complete streets concept.

The objective of this research was to develop guidance for design decisions to best balance competing needs to accommodate all expected road users. This goal was pursued by evaluating the implications of non-standard design solutions in terms of operational and safety considerations. Many of the non-standard design variables considered were initiated as part of a complete streets implementation. In essence, the complete streets philosophy supports designs that allow for safe usage of a roadway by all road users, regardless of mode. This idea often involves narrowing lanes to reduce the speed of motorists or even removing lanes, as in the case of a "road diet," in an effort to provide right-of-way for bicycle/pedestrian facilities. These cross-sectional changes can be in conflict with State Aid Design Standards. Limitation in right-of-way width require variations in standards if all modes are to be accommodated. Hence, it was necessary to evaluate the implications of modifying these standards, particularly from a safety perspective, to better accommodate various roadway users.

The report begins with a comprehensive literature review focusing on context-sensitive solutions (CSS), complete streets, and design standards. Initially, the history of the CSS movement is discussed, leading to a focus on current national practices in states including Wisconsin, Michigan, Indiana, and Minnesota. Special attention is given to the definition of 'complete streets' for the State of Minnesota as well as the legislative background surrounding complete streets in the state through discussion of key documents such as the "Complete Streets Report." Individual components and aspects of complete street implementations such as right-of-way issues and accommodation of both motorized and non-motorized traffic modes are also discussed. In order to better accommodate alternate, non-motorized modes, traffic calming strategies are often pursued, in many cases to help with speed control and management. A variety of state-of-the-practice traffic calming techniques seen in many current complete street implementations are presented; examples include curb extensions used as bus stops, speed tables, and chicanes. Current non-standard design elements and design strategies are also discussed.

Such design elements include narrowed lanes, two-way-left-turn lanes (TWLTLs), and bicycle boulevards. Narrowed lanes and TWLTLs are commonly used together in the implementation of road diets (also referred to as lane reductions). The final section of the literature review focuses on the Minnesota State-Aid Program. Design standards for new and reconstruction projects are outlined, followed by discussion of the State Aid Variance Process, plan implementation for a complete streets policy, and potential barriers to complete streets implementation at the local level as identified by the Minnesota Department of Transportation (MnDOT), local and federal agencies, and other stakeholders.

A brief review of stakeholder correspondence is provided in Chapter 3. The main focus of this section was to recap a workshop involving the research team, as well as representatives from different sections of MnDOT, the Minnesota Complete Streets Coalition, the University of Minnesota, Hennepin and Kandiyohi Counties, and the cities of St. Paul and Minneapolis. There were two main objectives of the workshop. The first was to identify locations where complete streets projects had been attempted or locations where complete streets projects should/could be attempted. The second was to develop a list of variables to consider with the implementation of complete streets elements. From the information provided at the stakeholders workshop, the research team was able to work with MnDOT staff to prioritize locations for this study.

Chapter 4 of the report presents a detailed analysis of 11 study sites at which CSS or other complete streets projects were implemented. As mentioned, sites selected were based upon the list developed at the aforementioned stakeholder meeting; 10 of the sites were in Minnesota, and 1 in Wisconsin. A detailed description of each site is provided to clearly outline the geometric conditions and right-of-way allocation prior to and following the reconstruction efforts. Additional site characteristics such as volume data, speed limits, and the extent of transit presence are also provided. In addition to general discussion of site conditions and a comprehensive before-after safety analysis was performed for each site. The safety analysis involved examination of crash data prior to and after reconstruction efforts at each site and involved two main components. The first component was a simple before-after analysis in which the percent difference in crashes between the before and after periods is directly calculated using the observed crash counts. The second component consisted of an Empirical Bayes (EB) analysis of each study site as is outlined in the *Highway Safety Manual* (HSM). The EB method calculates the expected crash frequency in the after period (crashes which would have occurred had no construction been implemented) and compares it with the observed crash frequency in the after period in a manner that eliminates the regression-to-the-mean effect observed in simple before-after studies. For the EB analysis, crashes were analyzed by number of vehicles involved (i.e., multiple vehicle or single vehicle), type (i.e., head on, angle, etc.), and severity (i.e., fatal and injury crashes versus property damage only crashes). Bicycle and pedestrian crashes were also examined, but only using the simple before-after study since no relevant safety performance functions (SPFs) were available to conduct EB analysis.

Chapter 5 presents a summary of the analysis as well as conclusions and findings. Differences in the characteristics of the study sites and varying degrees of changes and improvements conducted at each site prevented an aggregate quantification of the implications of complete street improvements across all sites, and specific recommendations for changes in design standards. Nevertheless, complete street improvements implemented at each study site did not indicate any significant impact on safety after reconstruction. Although quantitative analysis of traffic operations was not possible due to data limitation, anecdotal review of each study site and input from local officials suggest that no significant operational impacts were experienced.

Overall, the analysis of complete street designs implemented at the 11 study sites suggest that changes made to these study sites did not result in adverse safety or operational impacts. Therefore, providing flexibility and modification to the State Aid Design Standards in the context of complete streets and conditions specified in this research appears to be a reasonable consideration.

Chapter 1: Introduction

1.1 Background

In recent years, the degree of modal split in traffic in the United States has continued to change with increased use of non-motorized modes of transportation. It may no longer be feasible to expand facilities in an effort to increase capacity for motor vehicles at the expense of other modes of transportation, which has been a common practice. As such, context-sensitive solutions to accommodate a variety of road users and modes are being pursued. Whether or not this change was motivated by legislation, changes in funding, new schools of thought on transportation and the environment, or a variety of other reasons, it is clear that new roadway designs intended to provide safe and efficient mobility for modes other than the automobile are becoming more common.

Although the idea of having facilities that can be safely and efficiently used by multiple modes sounds good in practice, it does raise some concerns. First, right-of-way is often constrained making new acquisition difficult, if not impossible. Thus, a limited amount of space must be shared by users who often have competing demands. To ensure safety of road users, it is often desirable that facilities be separated or only partially shared. History has shown that competing needs of road users has often resulted in preference being given to automobiles at the expense of non-motorized users (i.e., bicyclists and pedestrians). For example, bicycle lanes may be eliminated or not implemented to provide lane widths meeting design standards for higher vehicle speeds. Typically, these design standards and guidelines come from one of two very different sources, namely research or existing practice. In the latter case, standards and guidelines are often developed and implemented without strong scientific basis. Despite efforts and legislation to provide adequate facilities for non-motorized road users, many newer design standards call for wider lane widths and increased vehicular capacity, hindering the provision for bicycle and pedestrian facilities. Questions remain as to best methodologies and standards necessary, given the existing constraints, to accommodate all users.

1.2 Introduction

It is with the aforementioned thoughts on design standards in mind that the concept for this study was developed. The objective of this research was to revisit the basis for selected design standards and develop guidance for design decisions to best balance competing needs to accommodate all expected road users. This goal was pursued by evaluating the implications of non-standard design solutions in terms of operational and safety considerations. Many of the non-standard designs considered can be classified as ‘complete streets,’ which have recently gained prominence. In essence, the complete streets philosophy supports designs that allow for safe usage of a roadway by all road users, regardless of mode. This idea often involves narrowing lanes to reduce the speed of motorists or even removing lanes, as in the case of a “road diet,” in an effort to provide right-of-way for bicycle/pedestrian facilities. With this brief definition in hand, one will see that this viewpoint is often in conflict with State Aid Design Standards that may call for lane widths, that when used, would prevent sufficient right-of-way from being available to install facilities such as bicycle lanes. Hence, it was necessary to evaluate the implications of modifying these standards, particularly from a safety perspective, to better accommodate various roadway users.

1.3 Structure

This report is intended to both review and analyze the implications of roadway designs, such as complete streets, that are intended to accommodate a variety of road users in an urban context. Chapter 2 presents a detailed literature review, which discusses both a history of the topics as well as the current state-of-the-practice in Minnesota and elsewhere. The literature review also focuses on various pieces of legislation that have helped motivate the usage of complete streets. Chapter 3 presents a brief summary of the project stakeholder meeting. At this meeting, attendees worked to develop a list of project study sites that have implemented complete streets changes as well as to outline topics to consider associated with complete street implementation. A list of 11 case studies covering a total of 12 project sites (11 in Minnesota and 1 in Wisconsin) is also presented in Chapter 3. Each study highlights a complete streets implementation and begins by presenting general information on the site location as well as the construction that took place. Roadway conditions in periods before and after the construction are discussed and images of the roadways in these periods are shown. After the background material is presented for a given site, detailed safety evaluation using different types of crash data in the periods of before and after construction (i.e., complete street implementation) are analyzed. Safety is evaluated using both simple before-after analysis as well as the Empirical Bayes methodology (where applicable). Chapter 5 concludes the report with a summary of key findings from the case studies, conclusions, and general recommendations and guidelines on the use of complete street improvements.

Chapter 2: Literature Review

2.1 General Background

2.1.1 History

Some of the earliest roots of the modern context-sensitive solutions (CSS) movement can be traced to the late 1950s. With the heightened interest in highway construction spurred by the 1956 Highway Act, efforts began to put in place policies to help plan the new system intelligently. A conference held at Syracuse University's Sagamore Center in 1958 focused on "the need to conduct the planning of urban transportation, including public transportation, on a region-wide, comprehensive basis in a manner that supported the orderly development of urban areas [1]." Importantly, the conference report recommended that projects be evaluated based on both user and non-user impacts. This recognition that urban transportation projects would have significant impacts on development of the surrounding environment, and that, accordingly such effects should be taken into consideration during the planning phase was an important first step. Unfortunately, putting policy into place requiring such planning would take several more years [1].

President John F. Kennedy addressed Congress in April 1962 regarding transportation, with a speech containing certain elements that foreshadowed the CSS movement. Kennedy's speech stressed the need to promote livability in urban areas as well as the relationship between community development and the proper balancing of modes. Congress was apparently listening. That same year, the Federal Highway Act of 1962 was passed, declaring that national interest dictated the development of transportation systems embracing various modes of transport, and requiring continuing, comprehensive planning for urban areas with more than 50,000 people. The recommendations from the Sagamore Conference were beginning to become policy [1].

A major step forward towards designing projects more in line with their surrounding environments came with the 1969 passage of the National Environmental Policy Act (NEPA). The Federal Highway Administration (FHWA) points to NEPA as the first significant milestone in the modern CSS movement. NEPA was also the first major environmental law in the U.S., and has had such a long reaching effect that it is sometimes referred to as the "Magna Carta" of environmental laws. Beyond simply being a policy to ensure protection of endangered species or prevent the destruction of natural resources, NEPA was realistic about the fact that human existence depended on a certain amount of development. Therefore, it also sought to encourage the well-informed planning of projects to protect more than simply the natural environment. As written into the language of the law, the goals of NEPA included [2]:

- Assuring for all Americans safe, healthful, productive, and aesthetically and culturally pleasing surroundings; and
- Preserve important historical, cultural, and natural aspects of our national heritage [2].

For transportation professionals, this now meant working with other agencies and specialties to ensure that their projects were carefully thought through. An Environmental Impact Statement (EIS) became the norm for projects both large and small. Projects now required collaboration between everyone from engineers to archeologists, social scientists to historians, and botanists to ornithologist to prepare a document often years in the making. Additionally, public concerns could be voiced and addressed. As stated by the Council on Environmental Quality—which oversees adherence to NEPA—the two major purposes of the environmental review process are better informed decisions and citizen involvement. Both of those stated purposes are keys to developing context sensitive solutions [2].

While NEPA greatly changed the way business was done in regards to transportation projects, it was not until the late 1990s that practitioners began to come together in force to articulate a vision for how transportation systems could better serve communities beyond simply moving traffic. In May of 1998, the American Association of State Highway and Transportation Officials (AASHTO) and the Maryland Department of Transportation conducted a workshop entitled "Thinking Beyond the Pavement." The main goals of the workshop included developing ways to [3]:

- "Find and publicize the best ways of integrating highways with their communities while maintaining safety and performance;
- Encourage continuous improvement in design of transportation projects across the nation, balancing all customers' concerns, whether transportation related or not; and
- Achieve flexible, context sensitive design in all projects" [3].

As seen in the goals of the workshop, participants were encouraged to brainstorm ways to "integrate" highways into communities, using "flexible, context sensitive design," and were presented case studies of success stories. In the end, the conference produced a list of recommended actions for various agencies including AASHTO, individual states, and organizations. Francis B. Francois, Executive Director of AASHTO at the time, summed up the goals of both the workshop and CSS succinctly: "Aesthetic, community-sensitive design is where our nation wants to go and we should go with them [3]."

The "Thinking Beyond the Pavement" workshop gave the CSS movement a great deal of momentum around the turn of the century. Well regarded professional organizations including AASHTO, FHWA, and the American Society of Civil Engineers (ASCE) began to embrace the movement, and by 2004 FHWA had even partnered in the launching of the website contextsensitivesolutions.org [3, 4]. By 2009, the Institute of Transportation Engineers (ITE) had published a recommended practice entitled *Designing Walkable Urban Thoroughfares: A Context Sensitive Approach*, which is the most comprehensive CSS design guide to date [5].

In addition to government and professional organizations, several advocacy groups embrace CSS as a means to further their own goals. The Congress for New Urbanism (CNU) is a national organization promoting smarter development, with principles that in many cases are in line with CSS. Founded in 1993 by a group of architects, the Congress now attracts over 1,000 people to its annual meeting, and has a stated goal of "creating sustainable, walkable, mixed-use neighborhoods that provide for better health and economic outcomes." Achieving such a goal necessitates the interdisciplinary approach embraced by CSS—accordingly, the CNU collaborated with ITE on *Designing Walkable Urban Thoroughfares* [5, 6].

2.1.2 Current Practice

2.1.2.1 National

The desire for CSS led to the development of the "Complete Street" concept. According to the National Complete Streets Coalition, "complete streets are designed and operated to enable safe access for all users. Pedestrians, bicyclists, motorists and bus riders of all ages and abilities are able to safely move along and across a complete street" [7].

Complete Streets policies encourage agencies to ensure that road projects are designed to meet local needs, be sensitive to context and emphasize that all modes of transportation and all users are considered in the planning and project development processes. Complete Streets policies are intended to provide a transportation *network* that promotes physical activity, accessibility, environmental quality, safety and mobility. Examples of Complete Streets goals and principles include [8]:

- Reduce crash rates and severity of crashes;
- Improve mobility and accessibility of all individuals including those with disabilities in accordance with the legal requirements of the ADA;
- Encourage mode shift to non-motorized transportation and transit;
- Reduce air and water pollution and reduce noise impacts;
- Increase transportation network connectivity;
- Maximize the efficient use of existing facilities;
- Strive for tax supported investments to provide maximum benefits to the community and all user groups;
- Safely integrate intermodal connections across the transportation network; and
- Promote safe and convenient access and travel for all users (pedestrians, bicyclists, transit riders) and people of all abilities as well as freight and motor vehicle drivers [8].

The national guidelines for constructing the Complete Street concept are outlined in the ITE Report *Designing Walkable Urban Thoroughfares: A Context Sensitive Approach*. It provides guidance for the design of walkable urban thoroughfares in places that currently support the mode of walking and in places where the community desires to provide a more walkable thoroughfare, and the context to support them in the future. While the concepts and principles of CSS are applicable to all types of transportation facilities, the report focuses on applying the concepts and principles in the planning and design of urban thoroughfares—facilities commonly designated by the conventional functional classifications of arterials and collectors [5].

The ITE report outlines the principles of CSS to promote a collaborative, multidisciplinary process that involves all stakeholders in planning and designing transportation facilities that [5]:

- Meet the needs of users and stakeholders;
- Align well with their setting and reinforce scenic, aesthetic, historic values, while preserving environmental resources;
- Allow for safe and efficient multi-modal use and are able to be maintained; and
- Reinforce community values and create a sense of place [5].

Traditional planning and design processes can be improved when principles of CSS are applied as issues outside of the transportation facility itself are also examined. In turn, considerations including surrounding existing and planned land use, the area economy, and environmental issues can also be addressed. The aforementioned stakeholder involvement helps gather input on project objectives, possible issues, and can further help balance competing demands throughout the project cycle (i.e., from planning through development). In summary, the report discusses how to apply CSS principles to both planning and design processes in an urban context, particularly those that have or intend to have significant pedestrian usage.

The objectives of the ITE report are to [5]:

1. Determine when and how to use CSS principles in roadway planning and design in an urban setting where substantial pedestrian facilities are desired;
2. Discuss the balancing of competing demands from various perspectives (e.g., from the stakeholder point of view, from the environmental point of view etc.);
3. Outline key tenets of CSS and show how they can improve transportation projects; and
4. Provide criteria that can be used to choose from a variety of thoroughfare types in order to select on best suiting a given community's needs. Further, provide guidelines to be used when designing the facility to best accommodate pedestrians [5].

2.1.2.1.1 Pedestrian Facilities

The ITE report defines walkable communities as "urban places that support walking as an important part of people's daily travel through a complementary relationship between transportation, land use and the urban design character of the place." The goal in creating a walkable community is to develop an area such that people want to walk as they realize it is a safe and efficient way to move about community. One may argue that most communities may be "walkable" as the vast majority have pedestrian facilities; however, one of the main criteria in defining a "walkable" community is that it is a place in which walking is not just possible, but also encouraged and enjoyable. Some defining criteria of walkable communities are listed as follows [5]:

1. All modes are accommodated in the urban setting and context sensitive solutions are applied when allocating right-of-way on a per-roadway basis;
2. Land use is allocated such that a variety of land use types (i.e., urban buildings, public spaces and landscapes) can be accessed easily and efficiently via walking;
3. Adequate capacity is provided for all modes and non-motorized users are provided with safe and efficient facilities (i.e., their needs will be accommodated without favoring motorists); and
4. Designs of roadways and the surrounding environment are dynamic in the sense that they can and will change over time [5].

Guidelines are established for the design of urban thoroughfares (primarily arterials and collectors) in walkable communities. These guidelines primarily apply to two situations [5]:

1. Projects in areas that would already be defined as walkable communities where the goal of the projects is to maintain or expand the degree of multimodal usage of a given facility; and
2. Projects in areas that want to establish themselves as walkable communities [5].

Both circumstances can apply to either new or reconstruction projects. Besides the aforementioned contexts, there are other areas in which the guidelines presented in the report can be applied. Primarily, these areas are those that want to adhere to some of the defining criteria of a walkable community, but may not want to pursue development on a community-wide level (e.g., a more isolated location such as a business park or subdivision). Benefits that may result from following guidance in the report include [5]:

- Enhanced pedestrian safety;

- Improved street side aesthetics;
- Savings during facility construction, operation, and maintenance;
- Increased transit use as a result of the facility placing a focus on transit (e.g., installing new stops etc.); and
- Increased adherence to speed limits as drivers may act more cautious when they know pedestrians are prominent [5].

2.1.2.2 Wisconsin

Wisconsin is among the thirty-eight states which have adopted legislation in support of Complete Streets. Approved in June 2009 and signed into law on March 11, 2010, the law says in part that the Wisconsin Department of Transportation (WisDOT) "shall ensure that bikeways and pedestrian ways are established in all new highway construction and reconstruction projects funded in whole or in part from state or federal funds". It was incorporated as State Statute § 84.01(35) and later into administrative rule as Transportation 75. Although there are exceptions for certain types of projects, the spirit of the law is intended to encourage the Complete Streets mindset in development of highway projects within the state [9].

Transportation 75.02 outlines when bikeways and sidewalk are required. The five points are [10]:

1. Except as provided in this chapter, the authority shall include bikeways and sidewalks in all new highway construction and reconstruction projects funded in whole or in part from state funds or federal funds appropriated under s. 20.395 or 20.866, Stats;
2. Sidewalks and bikeways shall be considered separately. If sidewalks and bikeways cannot both be accommodated, consideration shall be given to sidewalks before adding bikeways;
3. Paths can be used to supplement on-road bicycle accommodations. In exceptional situations a path may substitute for on-road bicycle accommodations if the use is consistent with the department's Bicycle Facility Design Handbook and the department's Facilities Development Manual and the substitution is approved in writing by the secretary's designee who has knowledge of the purpose and design of bicycle and pedestrian accommodations. A path may be considered along a controlled access highway, as defined in s. 990.01 (5r), Stats., having a speed limit of 45 miles per hour or higher;
4. The department shall refuse to provide any state funds or federal funds appropriated under s. 20.395 or 20.866, Stats., for any highway construction or reconstruction project that does not include bikeways and sidewalks required under s. 84.01 (35), Stats., and not excepted by this chapter. If an authority determines to omit any bikeway or sidewalk under this chapter, the department may request from the authority a written justification for the omission and shall deny state funds or federal funds appropriated under s. 20.395 or 20.866, Stats., for the project if the department determines the omission is not justified under this chapter; and
5. Notwithstanding sub. (1), bikeways and sidewalks are not required to be included in any highway construction or reconstruction project that is any of the following:

    (a) Has a program level scoping document consistent with life cycle 11 of the department's Facilities Development Manual or, for projects undertaken by a local unit of government, a similar document as determine by the department, in place as of January 1, 2011;

(b) Let for bid that is first advertised before January 1, 2011, or for projects for which no bid is advertised or undertaken under a contract signed before January 1, 2011;
(c) Described in a final environmental impact statement that is approved before January 1, 2011;
(d) Documented in an environmental report, as defined in s. Trans 400.04 (10), completed before January 1, 2011, that fit the criteria or conditions for approval as a categorical exclusion in 23 CFR 771.117, April 1, 2000; or
(e) The subject of a finding of no significant impact made under ch. Trans 400 before January 1, 2011 [10].

Transportation 75.04 of the report goes on to give restrictions as to why bicycles or pedestrians facilities would be prohibited. The Statutes gives the following [10]:

1. Section Trans 75.02 does not require bikeways or sidewalks to be included on any highway on which bicycles or pedestrians are prohibited by any of the following:
   (a) Order, ordinance or resolution under s. 349.105, Stats., regarding use of a freeway or expressway;
   (b) Ordinance under s. 349.18, Stats., regarding the operation of bicycles on the highway;
   (c) Ordinance under s. 349.23 (3), Stats., regarding use of a roadway; or
   (d) Order, ordinance or resolution under s. 349.185 (2), Stats., regarding pedestrians upon highways; and
2. If bicycles or pedestrians, but not both, are prohibited from using the highway, the project shall include either a bikeway or sidewalk, as appropriate, to serve the bicycles or pedestrians that are allowed to use the highway. A path may be considered along a controlled access highway, as defined in s. 990.01 (5r), Stats., having a speed limit of 45 miles per hour or higher where bicyclists and pedestrians are not allowed to use the roadway [10].

Transportation 75.04 delves into reasons why pedestrian or bicycle facilities would not be acceptable because of disproportionate costs. Reasons are as follows [10]:

1. WHEN FACILITIES ARE NOT REQUIRED. Notwithstanding s. Trans 75.02, bikeways and sidewalks are not required on any highway on which the cost of establishing bikeways or sidewalks would be excessively disproportionate to the need or probable use of the bikeways or sidewalks. Cost is excessively disproportionate to the need or probable use of the bikeways or sidewalks if it exceeds 20 percent of the estimated total project cost;
2. COSTS CONSIDERED. The cost of establishing a bikeway or sidewalk shall consider only the marginal cost of establishing any new or expanded bikeway or sidewalk and may not include any cost to reestablish any existing bikeway or sidewalk. Costs shall include only construction costs and the cost to acquire any real estate needed for a bikeway or sidewalk. Only 20 percent of the cost to acquire real estate needed for a bikeway or sidewalk shall be considered a cost of the bikeway or sidewalk if all the following apply:
   (a) Existing right-of-way is sufficiently wide to establish the bikeway and sidewalk were the highway construction or reconstruction project to occur without any additional travel lane; and

   (b) Additional real estate is needed to accommodate all needed travel lanes, bikeways and sidewalks;
3. APPORTIONING MONEYS. If the sum of costs for both sidewalk and bikeways exceeds 20 percent of the estimated total project cost, but the costs of either sidewalks or bikeways is less than 20 percent of the estimated total project cost, the authority may give more consideration to the inclusion of sidewalks as required in s. Trans 75.02 (2). The highway project shall include whichever of bikeways or sidewalks, or portions thereof, the authority, in consultation with the department, determines will provide the best value and costs 20 percent or less than the estimated total project costs. The highway project shall expend up to 20 percent of estimated total project costs on establishing sidewalks or bikeways or both; and
4. DOCUMENTATION AND APPROVAL REQUIRED. Notwithstanding s. Trans 75.02 (4), if an authority determines that bikeways and sidewalks are not required under this section, the authority shall submit to the department a written justification for the exception as part of any agreement concerning funding for the highway construction and reconstruction project from any appropriation of state or federal funds under s. 20.395 or 20.866, Stats. If the department receives a justification under this subsection, the department may approve the expenditure of moneys from any state or federal appropriation under s. 20395 or 20.866, Stats., for the highway project only if the secretary of transportation, or the secretary's designee who has knowledge of the purpose and value of bicycle and pedestrian accommodations, finds that the exception under this subsection applies [10].

2.1.2.3 Michigan

Complete Streets legislation (Public Acts 134 and 135), signed on August 1, 2010, gives new project planning and coordination responsibilities to city, county, and state transportation agencies across Michigan. The legislation defines Complete Streets as "roadways planned, designed, and constructed to provide appropriate access to all legal users…whether by car, truck, transit, assistive device, foot or bicycle [11, 12]."

The law further requires Complete Streets policies be sensitive to the local context, and consider the functional class, cost, and mobility needs of all legal users. The primary purpose of these new laws is to encourage development of Complete Streets as appropriate to the context and cost of a project [11].

To further assist this purpose, Public Act 135 provides for the appointment of a Complete Streets Advisory Council, comprised of representatives from 18 statewide government and non-government stakeholder agencies. The Complete Streets Advisory Council will provide education and advice to the State Transportation Commission, county road commissions, municipalities, interest groups, and the public on the development, implementation, and coordination of Complete Streets policies [12].

2.1.2.4 Indiana

Indiana is also working on incorporating complete streets into the legislature. They are in the process under House Bill No. 1354. What follows are sections of that bill [13].

Complete streets guidelines. Requires that Indiana department of transportation (INDOT) to do the following [13]:

1. Adopt guidelines for INDOT projects regarding street design that enables safe, comfortable, and convenient access for all users (complete streets guidelines);
2. Include a requirement to comply with complete streets guidelines in INDOT contracts entered into after December 31, 2011;
3. Include complete street guidelines in INDOT's approved design manual; and
4. Report to the general assembly in INDOT's progress in incorporating complete streets guidelines into manual and projects [13].

All is retroactively in effect by July 1, 2011 [13].

The following was also added to INDOT's guidelines through House Bill No. 1354 [13]:

1. For purposes of this section, "complete street" means a highway, street, or other roadway that is designed and operated to enable safe, comfortable, and convenient access for all users;
2. This section applies to a contract entered into by the department and contractor after December 31, 2011, for the planning, design, construction, reconstruction, or improvement of a state highway or other roadway that is under the jurisdiction of the department;
3. The department shall include in a contract, including any specifications or other documents that are a part of or incorporated into a contract, a requirement that he project be completed in accordance with the department's complete streets guidelines adopted under subsection (d). However, the department may exclude a project or part of a project form the requirement if:
    (a) Pedestrian or other non-motorized usage is prohibited by law on the highway, street, or other roadway that is the subject of the project or part of a project;
    (b) The cost of incorporating complete streets guidelines for the project or part of the project is excessively disproportionate to the benefits, as determined by the department; or
    (c) There is a demonstrated lack of present or future need for complete streets for the project or part of the project;
4. The department shall adopt guidelines to incorporate complete streets into the planning, design, construction, reconstruction, or improvement of a state highway or other roadway that is under the jurisdiction of the department. Guidelines adopted under this subsection must take into consideration the following:
    (a) The ages and abilities of all potential users of roadways;
    (b) The modes of transportation used on roadways; and
    (c) Safety, accessibility, and livability;
5. Not later than November 1, 2012, the department shall report in an electronic format under IC 5-14-6 to the general assembly the progress made by the department in implementing this section and incorporating complete streets guidelines into the department's approved design manual under IC 8-23-5-10. This subsection expires December 31, 2012; and
6. Beginning November 1, 2013, and not later than November 1 of each year, the department shall report in an electronic format under IC 5-14-6 to the general assembly on the number, type, and status of complete streets projects undertaken by the department. This subsection expires December 31, 2017 [13].

2.1.2.5 Minnesota (Statutory Definition & Legislative Background)

The *Street Design and Transportation* informational packet provided through http://www.lpa.state.mn.us/ helps give state employees guidance on Minnesota Statutes that must be followed when a new or reconstruction project is to take place. Following is information from that packet [14].

Transportation plans and street design ordinances can be adopted by counties, cities and townships under Minnesota Statutes which convey to them the power to plan and zone. These are [14]:

- **For Townships** – Minnesota Statutes § 366.10 through § 366.18 convey to townships the authority to enact zoning regulations, zoning districts and establish zoning commissions and prescribes the manner in which this is to be done. Minnesota Statutes § 394.33 also conveys to townships the authority to plan and zone with the stipulation that any official controls, after adoption, must not be inconsistent nor less restrictive than any adopted official controls of the county within which it belongs. Minnesota Statutes § 462.352 Definitions, subdivision 2. Municipality defines "municipality" to mean any city, including a city operating under a home rule charter, and any town, thereby extending all the authority grated to municipalities to plan per Minnesota Statutes Chapter 462 – Housing, Redevelopment, Planning, Zoning – to townships as well;
- **For Counties** – Minnesota Statutes § 394.21 specifically grants to all counties, except those in the defined seven-county metropolitan Area, the authority to "carry on county planning and zoning." Minnesota Statutes § 394.23 gives county boards the power and authority to prepare and adopt by ordinance, a comprehensive plan, "a comprehensive plan or plans when adopted by ordinance must be the basis for official controls adopted under the provisions of sections 394.21 to 394.37"; and
- **For Municipalities** – Minnesota Statutes § 462.353 grants municipalities the authority to plan. Subdivision 1. states, "A municipality may carry on comprehensive municipal planning activities for guiding the future development and improvement of the municipality and may prepare, adopt, and amend a comprehensive municipal plan and implement such a plan by ordinance and other official actions in accordance with the provisions of sections 462.351 to 462.364" [14].

The seven metro counties are governed by Minnesota Statutes Chapter 473, the Metropolitan Planning Act [14]. For cities in the seven-county metropolitan area, Minnesota Statutes § 473.858 – Comprehensive Plans – governs [14]. However, there are a number of specific Minnesota Statutes that convey and control local authority regarding roads and roadways. Attention should be directed to the specific Minnesota Statutes Chapter 160 – Roads, General Provisions, Chapter 161 – Trunk Highways, Chapter 162 – State-aid Road Systems, Chapter 163 – County Highways, Chapter 164 – Town Roads and Chapter 165 – Bridges [14]. Minnesota Statues § 160.01 – Scope of chapters 160 to 165 reads as follows [14]:

- Subdivision 1. **Designation**. For the purposes of chapters 160 to 165 the roads of this state shall be designated and referred to as trunk highways, county state-aid highways, municipal state-aid streets, county highways, and town roads. They shall be established, located, constructed, reconstructed, improved, and maintained as provided in chapters 160 to 165 and acts amendatory thereto; and

- Subdivision 2. **Certain streets excluded**. The provisions of chapters 160 to 165 do not relate to highways or streets established by, or under the complete jurisdiction of cities except when the provisions refer specifically to such highways or streets [14].

Also Minnesota Rules, specifically Chapter 8820 – Local state-aid route standards, financing, and specifically it's § 8820.2500 establishes the minimum state standards for geometric design standards, roadways, specifications, right-of-ways, and parking [14].

In the end, these Minnesota Statutes must be taken into consideration for new or reconstruction projects.

2.1.2.6 Minnesota (Specific Practices)

There are many design resources used in Minnesota that describe rules, guidelines, procedures, specifications, and references for corridor design. There is no strict hierarchy among them, as each resource has a unique role and is intended to complement the others while offering unique information. The following are key design resources currently used in Minnesota [8].

- **The American Association of State Highway and Transportation Officials (AASHTO) published *A Policy on Geometric Design of Highways and Streets, 6th Edition (Green Book*)** in 2011. It is a national policy that was developed through AASHTO and includes pooled knowledge of standard practices. This AASHTO policy is intended as a guideline and *NOT* as design standards; however, certain criteria have been adopted by the FHWA as standards for the National Highway System (NHS). Additionally, this policy is often used by states as the basis for their individual policies. This does not have enforceability on designs on Minnesota transportation facilities.
- AASHTO also published a *Guide for the Development of Bicycle Facilities*. The most recent (4th edition), was published in 2012 and similarly does not contain design standards. Nevertheless, the guide does outline suggested minimum dimensions for bicycle facility designs that designers can look to for guidance;
- **The *MnDOT Road Design Manual*** was developed using many practices established in the *Green Book*; however, it has criteria and value ranges that differ from AASHTO criteria. The *MnDOT Road Design Manual* can be considered the "hub" of transportation design in Minnesota - the starting point for a Trunk Highway design project. It establishes uniform design practices statewide but also provides enough flexibility to encourage independent design. It is primarily intended for design of the Trunk Highway system, and governs thirteen critical design criteria on trunk highways but it can also be used for local roads;
- ***MnDOT's Bikeway Facility Design Manual, Minnesota Manual on Uniform Traffic Control Devices* and *Bridge Design Manual*** are examples of specialized manuals that are typically used in tandem with the *MnDOT Road Design Manual.* These specialized manuals complement the information provided in the *MnDOT Road Design Manual,* while offering more specific design guidance; and
- ***MnDOT's State Aid Manual*** is a stand-alone resource that provides guidance when designing for State Aid roads and streets using State Aid funds. While most of the important design practices in this manual are the same as those in the *MnDOT Road Design Manual*, it identifies some criteria and value ranges developed by a statutory committee of city and county councilpersons, board members, and engineers for the specific needs of their State Aid roads which require formal variances for deviations. Much of the guidance

found in *MnDOT's State Aid Manual* focuses on topics such as determining whether or not a project is eligible for receiving government funding and the project delivery process. As such, designers are required to consult other resources, such as those aforementioned, for additional guidance in the facility design process. Local non-State Aid roads do not need to adhere to these standards; however, local agencies tend to default to State Aid standards, even on non-State Aid routes, to provide consistency within their jurisdictions [8]. Explicit requirements when using state aid or federal aid are discussed in Section 2.5 of this report.

Integration of the existing Minnesota design manuals into one manual has been suggested; however, the feasibility of this needs to be further explored.

<u>2.1.2.7 Minnesota Complete Streets Report</u>

The "Complete Streets Report" commissioned for the Minnesota Legislature and prepared by the Minnesota Department of Transportation was completed in response to the legislative directive to the Commissioner of Transportation to study the costs, benefits, and feasibility of implementing a Complete Streets Policy. The following contents are outlined in Laws 2008, Chapter 350, Article 1, Section 94 of the Minnesota Session Laws [8].

The commissioner of transportation, in cooperation with the Metropolitan Council and representatives of counties, statutory, and home rule charter cities, and towns, shall study the benefits, feasibility, and cost of adopting a complete streets policy applicable to plans to construct, reconstruct, and relocate streets and roads that includes the following elements:

1. Safe access for all users, including pedestrians, bicyclists, motorists, and transit riders;
2. Bicycle and pedestrian ways in urbanized areas except where bicyclists and pedestrians are prohibited by law, where costs would be excessively disproportionate, and where there is no need for bicycle and pedestrian ways;
3. Paved shoulders on rural roads;
4. Safe pedestrian travel, including for people with disabilities, on sidewalks and street crossings;
5. Utilization of the latest and best design standards; and
6. Consistency of complete streets plan with community context [8].

2.2 Individual Components/Aspects

2.2.1 Complete Streets Overview

Unlike more classical roadway design methodologies, practices for design of complete streets are frequently changing and are highly dependent on the specific context/environment the roadway exists in. Regardless, ensuring user safety and maintaining efficient mobility for all road users are still the most important concerns in the design process. One of the initial steps in the design of a complete streets project involves evaluating several factors that will ultimately govern the design. Such factors include typical considerations in transportation projects such as mode volumes, right-of-way restrictions, location of utilities, and delivering a project at or under the specified budget. Complete streets projects, however, introduce many new items for designers to consider such as placing more emphasis on the types of users (i.e., modal split with special attention being given to non-motorized users) and ensuring proposed solutions that align well with community image and values. Designers must also be cognizant of the street's purpose as defined according to its functional classification and realize that adding or removing items from the cross-section may not affect one user group, but could drastically affect the safety of another. AASHTO recognizes the preceding requirement in the following excerpt from *A Guide for Achieving Flexibility in Highway Design* [7]:

> *"Only by understanding the actual functional basis of the criteria and design values can designers and transportation agencies recognize where, to what extent and under what conditions a design value outside the typical range can be accepted as reasonably safe and appropriate for the site-specific context"* [7].

One of the most difficult issues in complete street design is being able to use all of the desired design elements within a limited right-of-way. Different user groups will have different desires; for instance, bicyclists may want in-road bicycle lanes, while motorists may feel more comfortable traveling in wide lane with significant shoulder space. The issue becomes more complex as user needs and desires will be expected to be balanced with the community's plan for the roadway (in terms of establishing a sense of place, or displaying their values). Thus, key elements that meet the needs of the majority, but do not compromise safety should be considered. As an example of the aforementioned issues, consider the following scenario. A designer is planning to reconstruct an urban arterial that processes high traffic volumes on a daily basis. Although he/she may want to use wide lanes in an attempt to increase throughput, he/she must also consider that roadside space for landscaping, street furniture, and utilities is quite important in many urban areas [7].

2.2.2 Right-of-Way Issues

As stated in the previous section, having limited right-of-way to work with for a project can make selecting design elements to meet the needs and desires of all users rather difficult. As such, the design elements to be included in the final design must be prioritized over those that are deemed less important. For complete streets projects, design elements of high priority include ones necessary to establish a truly context sensitive solution that meets stakeholder needs and aligns with the community's vision. The design elements that are deemed of low priority ultimately should not be pursued for inclusion in the final design. It has been recommended to develop a variety of possible cross-sections for any given design to help prioritize design elements. Four example design scenarios are presented as follows [7]:

1. Optimal conditions – what the design would be like if there were no spatial constraints;
2. Predominant – what the design would be like if it must be developed within in the typical (or predominant) right-of-way that exists throughout the rest of the corridor and where all high-priority elements can be included;
3. Functional minimum – what the design would be like when available right-of-way is constrained but there are still many options for pursuing installation of higher priority elements; and
4. Absolute minimum – what the design would be like when available right-of-way is highly constrained; only the most important elements can be pursued [7].

For long range plans, designers should make it a goal to reach the optimal design in the future [7].

2.2.3 Traffic – Motorized

2.2.3.1 Multiple Mode Accommodation

When designing an urban thoroughfare, local needs must be balanced with the facility's intended function in the wider transportation network (i.e., regional, etc.). Additionally, the facility should be planned such that it attempts to meet the needs of businesses and other land owners along the right-of-way, while also aligning with the characteristics and values of the surrounding neighborhood and community; this can be a complicated task as the level of activity in these two areas as well as their respective needs and desires can be quite different [5].

Networks of thoroughfares begin with an area's facilities in their existing conditions and grow/expand under the area's long-range transportation plan developed by their metropolitan planning agency or any other planning agency. When planning and designing a thoroughfare, it is important that considerations, such as network density, facility capacity (on a per mode level), and right-of-way allocation align with and enhance development, land use, and density as outlined in the long-term plan. Facilities should not be isolated, but rather integrated such that they form a network that supports safe and efficient multimodal transportation as well as community needs, goals, and values [5].

The following outlines key components of the philosophy on planning and designing networks of urban thoroughfares while applying principles of context sensitive design and prioritizing the creation of a walkable environment [5]:

- Long range transportation and urban planning should not only consider, but emphasize the establishment of a multimodal network;
- Providing adequate mobility and access along a network for varying types of transportation (i.e., travel, shipping, etc.) is essential; and
- Community goals and providing adequate mobility into the future should be considered in the long-term plan for an area. Additionally, reservation of right-of-way for expansion of thoroughfares in the future should be considered as a part of the plan [5].

2.2.3.2 Parking

Typically, the provision of on-street parking should only be considered for facilities on which the posted speed limit is less than or equal to 35 mph on account of the possible hazard created by vehicle maneuvers in and out of the parking spaces. Consideration of the demographic of the area can be helpful for deciding what kind of parking to provide, as well as the duration of parking. The following includes information and guidance that can be used to decide if parking may be provided in an area and how it could be regulated [5].

Provision of parking on urban thoroughfares is an important consideration in the planning and design processes of a facility as on-street parking can help meet the needs of adjacent businesses, provide physical separation between pedestrian facilities and travel lanes to promote safety, and lead to increased activity on the street. Typically, on-street parking provided on a given facility cannot accommodate all of the traffic coming to the area; its purpose is often not to do so, but rather to expand the total amount of parking available beyond off-street facilities. Following are some general principles and considerations regarding on-street parking [5]:

- The decision to provide on-street parking should be based on the characteristics of the thoroughfare type, needs of the adjacent land uses. and applicable local policies and plans for parking management;
- Higher-volume facilities such as urban arterials and avenues should make use of parallel parking when possible. Low-speed and low-volume facilities and "streets with ground floor commercial uses" may use angle parking [15, 16]:
  - The Minnesota State Aid Manual 2011 Chapter 5.4 Section VIII.A paragraph 3 states "Diagonal parking provisions must be established by cooperative agreement between the local road authority and the Commissioner of Transportation if the street width and traffic volumes meets standards in State Aid Rules 8820.9961, and the legal speed limit is 30 mph or less. Pavement markings for parking stalls must be completed before final acceptance of the project."; and
  - Minnesota State Aid Rule 8820.9961 (Minimum Design Standards for 45-Degree and 60-Degree Pull-in Diagonal Parking), states "diagonal parking projects must meet or exceed the minimum dimensions indicated in the following design chart (Table 2.1)";

Table 2.1: Minimum Design Standards for 45-Degree and 60-Degree Pull-In Diagonal Parking

Parking Angle	Present ADT	Parking Stall Width (feet)	Parking Stall Depth (feet)	Distance Between Traffic Lane and Parking Stall (feet)	Length Along Curb (feet)
45 degrees	< 3000	9	20	2	12.7
60 degrees	< 3000	9	21	7	10.4
45 degrees	≥ 3000	9	20	14	12.7
60 degrees	≥ 3000	9	21	19	10.4

    - Maximum legal speed limit must be 30 mph;
    - At least two through-traffic lanes must be provided;
    - Diagonal parking provisions must be established by cooperative agreement between the local road authority and the commissioner;
    - The cooperative agreement must show the angle of parking and provide for pavement marking of the parking lanes;
    - Minnesota Statutes, section 169.34, must be adhered to in determining diagonal parking spacing; and
    - Provide a two-foot clearance from the face of the curb to fixed objects. Parking meters, when spaced so as to not interfere with vehicle operation, are exempt;
- Facilities with speeds higher than 35 mph should not use on-street parking due to the potential of incident occurrence when a motorist maneuvers to enter or leave a parking space;
- The width of a parking space is not fixed; it depends on the setting, roadway type, and expected parking rate of parking turnover;
- Ensure local and PROWAG accessibility requirements are met and provide a sufficient number of accessible spaces;

- If long-term parking is discouraged, make use of a metering scheme or other similar system to enforce parking short-term time limits.
    - Price schemes are often developed through trial and error in an effort to ensure turnover rate is high and to attempt to minimize motorist reliance for on-street parking; and
- In areas where development is ongoing or expected, plan to include enough parking spaces to accommodate future land use density. If additional parking is needed, one may investigate the possibility of constructing parking structures as either stand-alone units or to be built as extensions of existing buildings [5].

AASHTO recommends that the preferred width of a parallel on-street parking lane be 8 feet wide on commercial thoroughfares or where there is an anticipated high turnover of parking and 7 feet wide on residential thoroughfares. These dimensions are inclusive of the gutter pan [5]. Furthermore, AASHTO recommends angled parking on low-volume (less than 4,000 ADT), low-speed (less than 25 mph) avenues and streets in commercial areas, where sufficient curb-to-curb width is available. Depending upon the angled use, the stall depth and curb overhang will change with respect to the minimum width of the adjacent lane. All stall widths should still be within the range of 8.5 to 9 feet wide. Head-in angled parking can create sight distance problems associated with vehicles backing out of parking spaces. The use of reverse (back-in) angled parking can be used to overcome sight distance concerns and is considered safer for bicyclists traveling adjacent to angled parking [5].

Some additional guidelines regarding on-street parking are as follows [5]:

- In some cases, the need for on-street parking may oppose the need to maintain adequate capacity. If this is the case, one may consider the possibility of making the curb lane an on-street parking lane in which vehicles can park solely during off-peak periods. During peak periods, the lane functions as a typical travel lane. Implementation of this strategy does bring with it new challenges such as the need for vigilant enforcement and possible safety issues as the physical separation between the pedestrian facilities and travel lanes is not continuously provided. If high volumes and congestion are negatively affecting nearby neighborhoods, this strategy should be used. Further, if mobility in a network is limited due to a small number of alternative routes, this strategy may also prove beneficial;
- Angled parking should be allowed in general urban context zones where operating speeds are 25 mph or less and where the delay caused by parking maneuvers is not detrimental to the community. The preferred configuration for angled parking is the diagonal back-in configuration; this is especially the case for bicycle routes. When considering the provision of angle parking, one must realize that using lower-angle parking will lead to the provision of fewer spaces; higher-angle parking necessitates a wider adjacent travel lane to allow exiting vehicles to maneuver without encroaching into the opposing travel lane;
- At least 1.5 feet of offset space should be provided from the face of the curb to the edge of the nearest obstruction at a location in which parallel parking is allowed. The offset is intended to minimize the potential for a motorist to damage a car door when opening it;
- Do not allow parking within 10 feet of a fire hydrant (see local codes for exact regulatory distances). Further, do not allow parking within at least 20 feet from nearside of midblock crosswalks (those without curb extensions) and at least 20 feet from the curb return of intersections (30 feet from an approach to a signalized intersection) unless curb extensions

are provided which all complies with Minnesota Statute 169.34 (Prohibitions; Stopping, Parking);

- Extending the curb by 6 feet into the parking lane at intersections and midblock locations can enhance visibility for pedestrians and allow for installation of additional street furniture and landscaping; and
- If reverse angled parking is used (i.e., parking where users need to back into the stall at an angle), designers must compensate for the longer overhanging section common in the rear of many vehicles. Additional width can be obtained by making the adjacent travel lane narrower as less space will be needed for maneuvering when exiting the stall and by through using a parking stall that does not extend as far back as in other cases (such as traditional angle parking) since the part of the vehicle's overhanging section will reside beyond the curb.
    - If reverse angled parking is considered, the edge zone lateral clearance must be at least 30 inches due to the added overhand of the rear of most vehicles [5].

2.2.4 Traffic - Non-Motorized

2.2.4.1 Pedestrian Refuge Islands

Refuge areas are provided at crossing locations (both intersection and midblock) in order to provide pedestrians and bicyclists with an area to stop temporarily if they cannot or choose not to cross the entire width of the roadway. Provision of refuge areas can be especially important for long crossings on wide thoroughfares and in locations where populations with limited mobility (such as the elderly) need to cross a street. Refuge islands also can make the process of crossing a complex multilane or multi-legged intersection simpler as crosswalks are broken up into shorter segments making the overall crossing of the intersection easier [5].

Refuge islands are commonly used and installed in medians and islands used for right-turn channelization. Designers may want to use them at midblock crossing locations if one of the following situations exists [5]:

- A midblock crossing of a high-volume roadway of at least four lanes exists and is unsignalized. Here, a refuge island could be used to break up the crossing such that bicyclists and pedestrians only have to focus on and complete a crossing of one set of lanes, in which all vehicles are traveling the same direction, at a time; or
- A midblock crossing exists that is used by many people (such as the elderly, children in a school zone, or people with disabilities) who walk slower than 3.5 feet per second (a speed commonly used for pedestrian signal timing). Here, use of an island would give the aforementioned groups a place of refuge if they were unable to cross the entire roadway [5].

When used at signalized intersections, pedestrian refuge islands increase the crossing distance of most pedestrians (assuming a walking speed of 3.5 to 4.0 feet per second) who do not actually need to use the refuge location. This can lead to increased traffic signal cycle lengths which can in turn increase delay. Some of the recommended practices for pedestrian refuge islands include the following [5]:

- Not unlike other traffic control devices, islands should command attention. Thus, they must be of sufficient size. A minimum area of 120 square feet with dimensions of 6 feet wide and 20 feet long is common for pedestrian refuge islands;
- In urban settings, refuge islands can help reduce pedestrian exposure to traffic. Designers may want to consider their use at unsignalized, wide (i.e., four or more lanes or at least 60 feet) urban crossings;
- When a median is to be used as a location for pedestrian refuge, it should have vertical curbs to provide physical separation from the roadway;
- If a refuge island is to be used at an intersection between a roadway and a multi-use path, it is recommended that the island be 10 feet wide (8 feet minimum); and
- Spaces in the island through which pedestrians temporarily stop and in turn pass through must match street grades and ensure accessibility by complying with regulations on detectable warnings and audio and visual output at signalized crossings [5].

2.2.4.2 Pedestrian Crossings

Issues surrounding the design and usage of crosswalks are not isolated to an individual intersection. When applying the principles of the context sensitive solutions philosophy to the design of a walkable community, the idea is to establish a useful network where pedestrians and bicyclists are common. Further, it is desirable to reinforce driver expectancy (that non-motorized users are present) by making use of consistent and uniform signs, pavement markings, etc. The following principles and considerations should help guide the planning or design of pedestrian crossings [5]:

- The designer should consider that pedestrians and bicyclists intend to go to any location a motorist can access. As such, the non-motorized users will expect to be able to access these locations in a safe manner. Further, the designer must consider that pedestrians will also need to be able to access many locations that a motorist otherwise could not;
- Residential neighborhoods, schools, parks, shopping areas and employment centers are frequent trip generators for both bicyclists and pedestrians. Thus, provision of crossings will likely be important in these locations. Additionally, many transit stops require that pedestrians be able to cross the street in order to board a vehicle or depart from it upon reaching a stop;
- Uncontrolled intersections and midblock crossings are locations that pedestrians commonly need safe access to;
- Providing crossings at regular intervals is extremely important for pedestrians. Unlike motorists, pedestrians should not be expected to go more than 300 to 400 feet out of their way to take advantage of a crossing at a controlled intersection;
- Intersections are preferred over midblock crossings when it comes to controlling motorized traffic to permit pedestrian crossings;
- Crosswalks must be easily understood and highly conspicuous in order to alert motorists of their presence and the associated possibility of pedestrians making a crossing maneuver. Additionally, they must be designed such that they provide for realistic/reasonable crossing opportunities for pedestrians;
- Common crosswalk markings area as follows: transverse, longitudinal, and diagonal (zebra) lines. Longitudinal markings should not be painted such that they are in line with normal wheel paths, and line spacing should not exceed 2.5 times the line width;

- When a traffic control device is not present to help control crossing maneuvers, special emphasis longitudinal or diagonal markings should be used to increase visibility. These markings can also help enhance visibility for people with some vision problems, but no *MUTCD* or Minnesota *MUTCD* provisions for the use of high-contrast pavement markings has yet been developed. It does state on page 744 of the 2005 Minnesota Spec Book Edition that "[Permanent] Pavement markings in Minnesota shall retain a satisfactory level of retro-reflectivity, demonstrate good adhesion, resisting chipping, and exhibit consistency of color in all lighting conditions.";
- Pedestrian signals used in highly urbanized areas, at compact signalized intersections and at other locations with higher levels of pedestrian activity, should show the WALK indication without requiring pedestrian activation via push-button; and
- Colored and textured crosswalk design treatments are sometimes used between transverse lines to enhance the conspicuity of the crosswalk. If a textured surface is used, one should ensure that the material used is smooth, nonslip and visible. Paver systems prone to movement, settlement, or that cause excessive vibration when traveled over (a concern for wheelchair users that must be considered) should not be used [5].

2.2.4.3 Bicycles

Accommodating bicycles on an urban thoroughfare can often be a challenge due to right-of-way constraints. Furthermore, not every bicyclist has the same skill level so accommodating all users can be a difficult challenge. That being said, having bicyclists sharing the roadway with drivers is preferred over them sharing the sidewalk with pedestrians. With bicyclists sharing the roadway, determination of the proper parking alignment must also be considered [5]. General principles and considerations for bicycle lanes are listed at the end of this section.

When planning and designing a truly multimodal street, provision of facilities for bicyclists is important. As is the case with drivers, there is a high level of variability between bicyclists with respect to their level of skill and confidence, trip purpose, and preference for facility types. As a result of these differences, bicyclist mobility needs and desires can vary significantly from one urban area to another. To accommodate these differences, bicycle facilities of multiple types (i.e., multi-use paths, in-road bicycle lanes, etc.) should be used to create a network that allows for safe and efficient bicycle travel [5].

In-road bicycle lanes will not necessarily be used on all urban thoroughfares; one must consider the context of the roadway when deciding whether or not to provide these facilities. That being said, bicyclists are allowed to travel on any street, with the exception of freeways and other streets where bicycling is prohibited by law, whether or not in-road bicycle lanes are present. Further guidance is outlined in Minnesota Statute 169.222 which highlights roadway position, overtaking procedures, and appropriate right-of-way. When a planner/designer considers whether or not to include in-road bicycle lanes the volumes and speed of traffic on the candidate roadway are two of the most critical factors with respect to providing safe facilities. If adequate facilities cannot be provided, the safety of both bicyclists and motorists is hindered. For urban settings, in-road bicycle lanes can either be installed adjacent to the curb or adjacent to on-street parking facilities [5].

Choosing to provide bicycle lanes can have many benefits including improving mobility, increasing accessibility, and increasing overall system capacity. General principles and considerations regarding bicycle lanes include the following [5]:

- "As published in *Selecting Roadway Design Treatments to Accommodate Bicyclists*, a 'design bicyclist' refers to the skill level of the bicyclist and, along with the factors described previously, affects decisions on implementation of bicycle lanes. The three types of bicyclists, each of which has different needs, are (1) advanced or experienced bicyclists (require facilities for directness and speed and are comfortable riding in traffic and shared lanes), (2) basic or casual bicyclists (require comfortable and direct routes on lower-speed and lower-volume thoroughfares and prefer separated and delineated bicycle facilities), and (3) children (require adult supervision and typically only travel on separated paths or very low-volume and low-speed residential streets)";
- When evaluating the possibility of installing bicycle lanes on major urban thoroughfares, several criteria should be used in the decision-making process including:
    - The degree of access and mobility the facilities will provide in the overall transportation network. Designers should be cognizant of whether or not they allow access to and from major origins and destinations along convenient routes; and
    - The degree of continuity in travel provided by the facility. Much of this has to do with geography in the area (e.g., large hills that may be difficult for bicyclists to climb, bodies of water that will need to be crossed, etc.);
- Bicycle lanes do not have to be installed on every street. Ideal candidates for installation include major thoroughfares with target speeds of 30 mph or more and streets with high traffic volumes and speeds less than 30 mph;
- If bicycle lanes are provided on parallel facilities, it does not mean they are not necessarily needed on a main street. In fact, having bicycle lanes in both of the aforementioned locations can increase access and safety as bicyclists often benefit from traffic control devices found on main streets;
- Although it can be difficult to satisfy the needs of all bicyclists due to highly variable skill and comfort levels, walkable urban thoroughfares should be designed to meet the needs of type 2 bicyclists (i.e., basic or casual bicyclists);
- Balancing the competing needs of bicyclists and motorists can be especially difficult in an urban setting due to right-of-way restrictions. That being said, one should not try to combine minimum dimensions to implement all of the desirable design elements, especially on designated bicycle routes;
- To promote bicyclist safety, it is often more important to ensure dimensions of bicycle lanes, curb lanes, and parking lanes are at the recommended or maximum levels and to avoid using other design elements. For example, it may be desirable to reduce the number of lanes in a cross-section of a four-lane undivided street to three with left-turn lanes to allow for the provision of bicycle lanes instead of simply reducing the width of all of the other design element to keep four lanes;
- Bicycle lanes next to head-in angled parking are not desirable as it can be difficult for a motorist backing out of a space to see a bicyclist. If head-in angled parking is present on a facility, converting it to parallel parking can help provide the width necessary for installing bicycle lanes;
- On one-way facilities, angled-parking stalls can be used on the left side of the street while the bicycle lane can reside next to parallel parking facilities on the right side of the roadway. Use of reverse (back-in) angled parking can help increase driver visibility of bicyclists (Figure 2.1); and

Figure 2.1: Reverse (Back-In) Angled Parking Improves Driver Visibility of Bicyclists [5]

- Even if the sidewalk is sufficiently wide, bicyclists should be discouraged from riding on sidewalks due to the safety concerns associated with conflicts with pedestrians; since bicyclists would likely be traveling at a higher speed than walking pedestrians, a crash could lead to severe injury for one or both parties. Further, bicyclist safety on sidewalks is often compromised due to the presence of sign poles and other street furniture. Potential for conflict with automobiles also exists at intersections and driveways as motorists likely do not expect bicyclists to travel through such locations on the sidewalk. Providing adequate facilities that allow safe and efficient mobility can reduce bicyclist desire to travel on sidewalks. Even though in-street lanes are the preferred choice when providing bicycle facilities, parallel routes and multi-use paths could prove more beneficial in certain situations [5].

2.3 Traffic Calming

2.3.1 Adoption/Incorporation onto a Grid System

Short blocks and straight, often parallel streets are common in traditional networks ("grid system"); further, the density of intersections is often high and the spacing between them can be small (due to short block length). The advantages of traditional grids include [5]:

- Traffic can be dispersed throughout the network instead of concentrating it onto a small subset of main thoroughfares. Thus, the stress produced by high traffic volumes on roadways of lower functional classifications, such as collectors, can be reduced;
- More direct routes to destinations are possible leading to a decrease in vehicle miles of travel (VMT);
- The presence of several convenient alternate routes that can help reduce delay in the event of an incident and improve overall travel time reliability;

- Improved multimodal circulation in an area;
- Encouraging the use of non-motorized modes of travel, such as walking or bicycling, due to the presence of direct routes along both high- or low-volume streets that can be used to access many destinations;
- Improved accessibility of transit stops;
- The possibility of evolving land use over time due to small block structure;
- Improved access to emergency sites by emergency providers due to the presence of predictable routes in a redundant system;
- Opportunities to coordinate traffic signals (due to their close spacing) to harmonize speeds, increase the degree of platooning, and provide more opportunities for pedestrian crossings; and
- The possibility for unique thoroughfare designs and uses [5].

2.3.2 Techniques, Devices, Options, Alternatives

2.3.2.1 Roundabouts

Roundabouts are becoming an increasingly popular option to replace stop controlled and signalized intersections. Although they may often have four legs like a traditional signalized intersection, roundabouts make use of a center island around which vehicles travel in a counterclockwise manner. They are often used on higher volume streets to assign right-of-way as a traffic signal would; thus, their main benefits are realized by drivers. Such potential benefits include improved flow conditions, increased capacity, and decreased stops and delay. In most cases, roundabouts make use of raised splitter islands to channelize both entering and exiting traffic. Studies have shown roundabouts can help improve safety by decreasing crash severity, reducing delay and queuing, and reducing operating costs (in terms of hardware installation and maintenance) when compared to traffic signals. Furthermore, roundabouts can be ideal candidates for usage at intersections with non-traditional geometry, intersections that must process a high volume of U-turns, and in areas in which right-of-way is abundant. Although the benefits of roundabouts can be numerous for motorists, they can be problematic for pedestrians. More particularly, roundabouts can be difficult for people with disabilities to cross as they typically do not have cues or devices to provide the same types of warnings (e.g., stop/start vehicle sounds, flashing lights, audible warnings) to alert pedestrians of whether or not it is safe to cross the roadway that may be in place at a signalized intersection [17, 18].

Additional benefits of roundabouts include the ability to help regulate speeds on high-volume roadways such as arterials and can be visually appealing as the center islands often contain landscaping. Although roundabouts can provide many benefits, they can also have some disadvantages. First of all, roundabouts can be hard for large vehicles, such as trucks or emergency vehicles, to traverse. Additionally, designers must make sure that the circulating lane does not conflict with crosswalks. Their large footprints may necessitate the removal of on-street parking in certain locations. As aforementioned, the center islands of roundabouts are often landscaped; this landscaping will require maintenance (e.g., lawn-mowing, etc.) and thus results in additional maintenance costs [18].

One study of 11 sites with roundabouts found that on average, crashes per year at the selected sites were reduced by 29% (from 9.3 to 5.9 crashes per year) [18]. In the Skycrest neighborhood of Clearwater, Florida, residents sponsored a plan to install six roundabouts in response to a perceived problem with speeding and aggressive driving in the area. A comprehensive benefit cost analysis (BCA) was performed following the installation to evaluate the possible gains to society in terms of a variety of safety, monetary, environmental, social, and transportation-related issues; of these factors, safety, particularly with respect to fatal crashes, was a major consideration. In a typical BCA, if the benefit to cost ratio is greater than one, it can deduce that the benefits of the project outweigh the costs examined. In the case of Clearwater, the benefit to cost ratio was 34.5, which highlights the degree to which the benefits of roundabouts outweighed the costs in this case [17].

2.3.2.2 Bus Stop Overview

When installing bus stops, choosing a location that maximizes safety and minimizes potential conflicts in an effort to maintain smooth flow is essential. Designers should also consider the installation of features to accommodate waiting passengers such as benches or shelters to protect them from the elements; if the decision is made not to install these features initially, one may want to consider their possible installation and thus choose a site location where sufficient right-of-way exists to allow for construction of these improvements in the future. That being said, choosing a stop location ultimately requires evaluation of numerous safety and operational aspects of a proposed area; information about some of these aspects can be gathered from thorough on-site examinations. Some important considerations when selecting a site for bus stop installation are as follows [19]:

Safety:

- Providing protection or separation of passengers from traffic in the roadway;
- Providing safe and easy access for people with disabilities;
- Making use of a non-slip or all-weather surface to provide traction for passengers and prevent slipping as they get on or off the bus;
- Choosing a location close to crosswalks and curb ramps to provide easy access;
- Choosing a location close to major trip generators (such as large retail spaces);
- Making it easy for passengers departing from one stop to transfer to another route at a nearby stop;
- Maintaining close proximity to stops on the same route for the opposite direction of travel; and
- Providing adequate lighting of the area [19].

Operating:

- Providing enough space for the expected number of buses to stop at a given time;
- Evaluating the potential effects of the bus stop on nearby properties;
- Evaluating the effects on on-street parking and truck delivery zones;
- Analyzing bus routing patterns, particularly at intersections;
- Analyzing the effects on other traffic in the area;
- Choosing a location with adequate sidewalk width;
- Analyzing pedestrian movements at intersections; and
- Evaluating the location of the stop with respect to location of the nearest driveways and the volumes of entering and exiting vehicles at those driveways [19].

Possible bus stop site configurations include far-side, near-side, and midblock stops. When choosing from these types of stops, one should consider the following [19]:

- Surrounding property and land use;
- Overall bus routes for all buses that travel through the area;
- Whether or not transit signal preemption is present in the area;
- How the stop will affect operational conditions at the nearest intersection;
- Layout of the intersection;
- Traffic control (if any) in use;
- Whether or not parking is allowed near the stop;
- Distribution of passenger trips;
- Limitations within the right-of-way (landscaping, sign poles, etc.);
- Degree of accessibility by all passengers, especially those with disabilities; and
- Whether or not a bus bypass lane exists in the area [19].

2.3.2.2.1 Bus Bump-Outs ("Nubs")
Curb extensions are commonly used for traffic calming, but they can also be used as bus stop. One type of curb extension used as a bus stop is called a bus bump-out (or nub). A bus bump-out is an area in which the curb of an indented parking lane has been extended to the edge of the outside through lane to provide space for a bus stop (see Figure 2.2). Buses hence stop outside of the parking lane and passengers board as they would at a curb-side stop. Benefits of bus bump-outs include more available space that can be used by passengers when they are waiting for a bus. Additionally, this increased amount of space can be used for installation of shelters and benches [19].

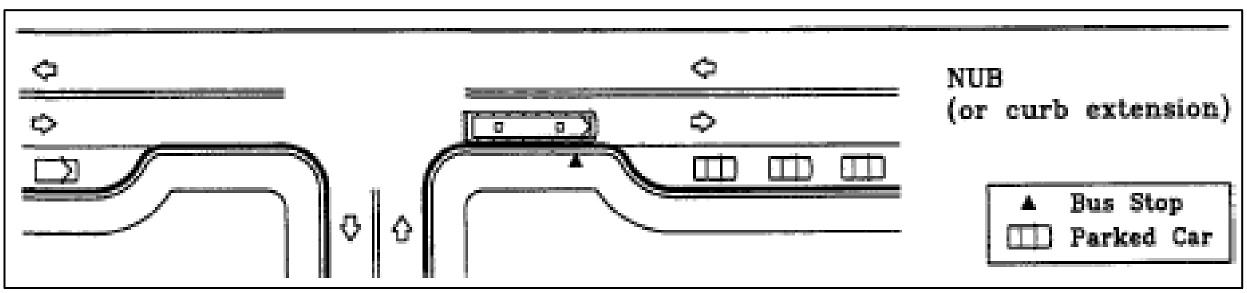

Figure 2.2: Bus Bump-Out ("Nub") [19]

Installation of nubs can be beneficial at sites with the following characteristics:

- High pedestrian volumes;
- Decreased pedestrian crossing distances; and
- Bus stops in travel lanes [19].

Advantages of nubs include fewer parking spaces being removed for a bus stop, decrease in walking distance and time for pedestrians crossing the street, additional sidewalk area for bus patrons to wait, and minimal delay for buses. Disadvantages of nubs are more cost to install compared with curbside stops, can cause traffic to queue behind a stopped bus thus causing traffic congestion, and may cause drivers to make unsafe maneuvers when changing lanes in order to avoid a stopped bus [19].

2.3.2.2.2 Bus Bays

A bus bay (or turnout) is an area indented from the travel lanes to provide space for a bus to pick up and drop off passengers (see Figure 2.3). One of the major benefits of this design is that it allows traffic to bypass a stopped bus instead of having to stop behind it as is the case at a a bus stop installed at a nub. As a result of this benefit, they are commonly used on high-volume and high-speed roadways like arterials. Besides these locations, they are often used in central business districts at stops where there are high volumes of passengers getting on and off the bus. Overall, bus bays can be categorized into three different configurations: bus bays with acceleration and deceleration lanes, open bus bays, and queue jumper bus bays with acceleration lanes [19].

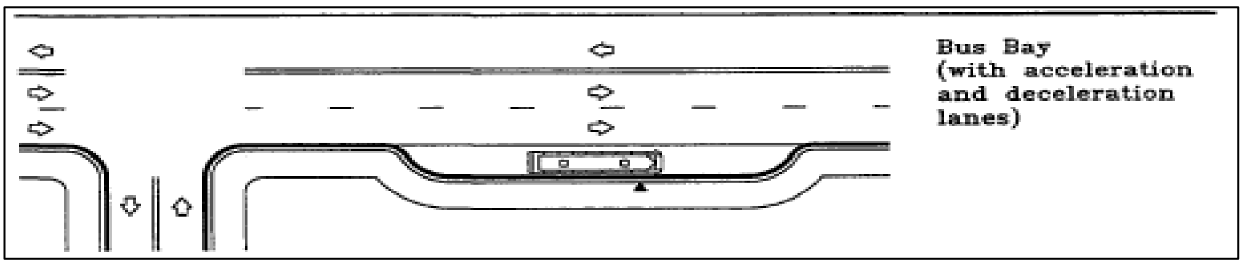

Figure 2.3: Bus Bay with Acceleration and Deceleration Lanes [19]

Advantages of a bus bay with acceleration and deceleration lanes are that it allows patrons to board and alight out of the travel lane, providing a protected area away from moving vehicles for both the stopped bus and the bus patrons, and minimizing through traffic delay. Disadvantage of a bus bay with acceleration and deceleration lanes are that it may present problems to bus drivers when attempting to re-enter traffic, especially during congested peak periods, are more expensive to install compared with nubs or curbside stops, and are more difficult and expensive to relocate [19].

An open bus bay is a variation of a standard bus bay as was prviously discussed. The open bus bay design features a bay that is open to transit vehicles traveling upstream of the intersection (see Figure 2.4). This design affords bus drivers the use of the width of the upstream cross street to reduce their speed and enter the bus bay [19].

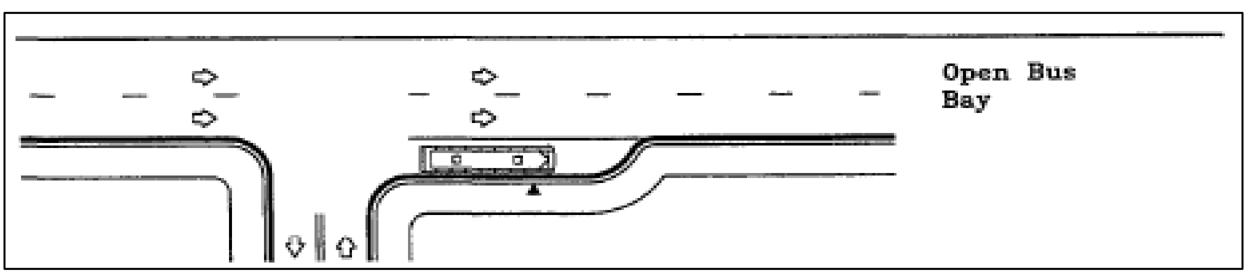

Figure 2.4: Open Bus Bay [19]

Advantages of an open bus bay are that it allows the bus to decelerate as it moves through the intersection along with the advantages highlighted with the bus bay with accelration and deceleration lanes. Disadvantages for an open bus bay are the same as those for a bus bay with acceleration and deceleration lanes [19].

Queue jumper bus bays can benefit buses on arterials as they give buses the opportunity to bypass queues at intersection. In terms of configuration, they are composed of an upstream right-turn lane and an open bus bay at the stop location. Buses can travel in the turn lane to bypass queues and smoothly traverse the intersection. In some cases, signage is used to denoted that only buses and right-turning vehicles can use the right turn lane. These types of stops benefit both typical drivers and buses. By removing buses from the traffic stream temporarily to help them bypass queues, queues for motorists are slightly reduced as buses will not be in them. An example of a queue jumper bus bay is shown in Figure 2.5 [19].

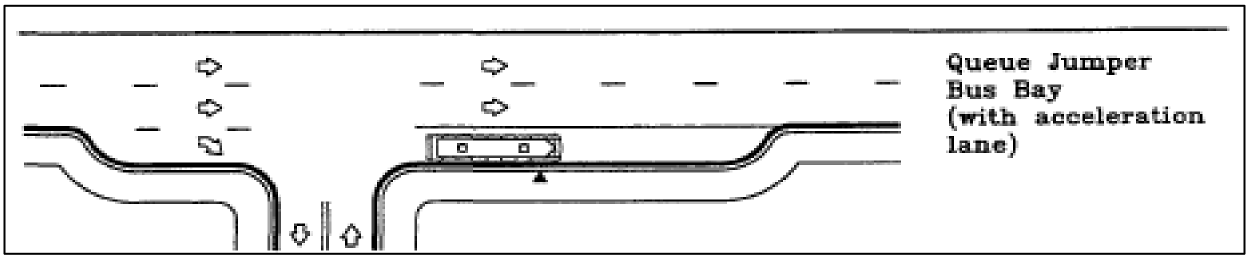

Figure 2.5: Queue Jumper Bus Bay with Acceleration Lane [19]

Advantage of a queue jumper bus bay with an acceleration lane is that it allows busses to bypass queues at a signal along with the advantages highlighted in the open bus bay. Disadvantages include delays to right-turning vehicles when a bus is at the start of the right-turn lane along with all the disadvantages outlined for a bus bay with acceleration and deceleration lanes [19].

2.3.2.3 Speed Humps

Speed humps are rounded, raised sections of pavement that travel across the roadway in a transverse direction. Commonly, they are 10 to 14 feet long in the longitudinal direction; hence, they are quite different from “speed bumps” one may see in a parking lot. In terms of shape, the humps are either circular, parabolic, or sinusoidal. In order to maintain adequate drainage, the profile is often decreased near curbs. An example of speed hump is shown in Figure 2.6 which does not cross into the bicycle lane on both ends of the travel lane. Speed humps are good for locations where very low speeds are desired and reasonable. They can, however, lead to higher noise and air pollution levels in an area. Speed hump markings are outlined in the Minnesota *MUTCD* in sections 3B-46 through 3B-49. Generally, if speed hump markings are used, they shall be a series of white markings placed on a speed hump to identify its location. The speed hump sign (W17-1) is also outlined in the Minnesota *MUTCD* in section 2C-20 [18].

Figure 2.6. Speed Hump in Burlington, North Carolina [18]

The advantages of speed humps are that they are relatively inexpensive to install, can be relatively easy for bicyclists to traverse, and can help with speed reduction. Disadvantages of speed humps include driver discomfort, forcing large vehicles (such as emergency vehicles and those with rigid suspensions) to travel at slower speeds to reduce impact, increased noise levels, aesthetics, and issues with snow plows clearing snow around them properly [18]. The effectiveness of a 12-foot speed hump, as shown in one study, is as follows [18]:

- From a sample of 179 sites, there was an average of 22% decrease in the 85th percentile travel speeds, or an average speed reduction of 35.0 to 27.4 miles per hour; and
- From a sample of 49 sites, there was an average of 11% decrease in crashes, or an average decrease of 2.7 to 2.4 crashes per year [18].

The effectiveness of a 14-foot speed hump, as shown in one study, is as follows [18]:

- From a sample of 15 sites, there was an average of 23% decrease in the 85th percentile travel speeds, or an average speed reduction of 33.3 to 25.6 miles per hour; and
- From a sample of 5 sites, there was an average of 41% decrease in crashes, or an average decrease of 4.4 to 2.6 crashes per year [18].

2.3.2.4 Speed Tables

Speed tables are a type of speed hump that feature a flat-topped area often made out of brick or another textured material. In general, speed tables are long enough such that the entire wheelbase of a passenger car will be able to rest on the flat-topped section. Higher design speeds can be used with speed tables than with speed humps due to their long, flat top portion. Aesthetics can be enhanced when brick or another textured material is used in their construction; these materials can also draw attention to them which may improve safety and help reduce the speed of drivers. An example of a speed table is shown in Figure 2.7 which is jointly used as a pedestrian crossing. It also has a brick textured top to enhance its visibility along with directional traffic arrows. Speed tables are ideal candidates for traffic calming treatments in areas that want to reduce speeds, but may also have significant volumes of larger vehicles traveling through the area [18].

Figure 2.7: Speed Table in Lincoln City, Oregon [18]

The advantages of speed tables are that they often produce less driver discomfort and have been shown to help reduce speeds; that being said, the reduction is not as great on average as can be achieved when using speed humps. Speed tables are most comfortable for bicyclists to traverse if they are designed to have gradual slopes and long, flat tops. One disadvantage of speed tables is that they are visually displeasing to some depending on the materials used for construction. This problem can be remedied by using textured materials such as bricks. However, the use of these materials will increase costs. Speed tables may increase noise and air pollution; and snow plows may have issues clearing around them properly. The comparative effectiveness of a 22-foot speed table, as shown in a study, are [18]:

- From a sample of 58 sites, there was an average of 18% decrease in the 85th percentile travel speeds, or an average speed reduction of 36.7 to 30.1 miles per hour; and
- From a sample of 8 sites, there was an average of 45% decrease in crashes, or an average decrease of 6.7 to 3.7 crashes per year [18].

2.3.2.5 Speed Cushions

A speed cushion, or speed slot, is a type of speed hump that features at-grade channels or pathways traveling in the longitudinal direction. The channels are used in order to accommodate wider-wheel-based emergency vehicles; more particularly, they allow these vehicles to traverse the hump with significantly reduced impact when compared to simply traveling over the raised portion. Additionally, motorcyclists and bicyclists are often able to travel in the channel area, in turn minimizing the effect of the hump on their comfort. An example of a speed cushion is shown in Figure 2.8 [20].

Figure 2.8: Speed Cushion in Seatac, Washington [20]

Many municipalities have started to use speed cushions as traffic-calming devices in residential areas. Designs in place today are highly variable and markings associated with them can also differ. Different designs often use different shapes/profiles, different materials for construction, different pavement markings schemes, and are sometimes are even different colors. Researchers are recommending that regional standards on the devices be developed to establish some degree of consistency and uniformity in their design in order to reduce driver confusion and reinforce their expectancies [20].

2.3.2.6 Chicanes

Chicanes are a type of curb extension that, when used, create a series of S-shaped curves. By extending the curb on one side of the roadway and in turn pushing back the curb on the other side, the curves (such as those seen in Figure 2.9) are created. Another method to create chicanes involves alternating the side of the street on which on-street parking (in the parallel or diagonal configuration) is allowed. Parking bays can be created via pavement markings or through installation of elevated island sections (that are often landscaped) at the ends of the bays. Figure 2.10 shows how using alternate on-street parking with using raised, landscaped islands at the ends of each parking bay creates a subtle yet effective chicane. Chicanes are ideal where speed control is desired, but the noise caused by other treatments such as speed humps would be a nuisance [18].

Figure 2.9: Chicane in Alachua, FL [18]

Figure 2.10: Alternate On-Street Parking Creates Chicane [18]

One advantage of chicanes is that they can help discourage speeding by forcing drivers to keep their speeds in check due to the frequent presence of horizontal curvature. Additionally, larger vehicles (such as emergency vehicles) can traverse them with relative ease. Disadvantages of chicanes include high costs associated with realigning the roadway and landscaping and potential loss of on-street parking, and that if they are not designed carefully. Also, designers must focus on designing the alignment in a manner that does not encourage drivers to leave their lanes as they traverse a curve as this could be rather dangerous due to potential conflicts [18].

2.4 Non-Standard Design Elements

2.4.1 Narrowed Lanes

In roadway design, 12 feet is the most common width for travelled lanes. Research has shown that a 12 foot width can improve safety and maximize the lane capacity of a facility. Nevertheless, guidance from AASHTO's *Green Book* and recent studies have shown that this practice is not always appropriate. In fact, it has now been shown that in some cases, narrower lane widths may improve safety due to increased driver awareness without a significant impact on safety.

The foreword to the AASHTO *Green Book* states that: "Minimum values are either given or implied by the lower value in a given range of values. The larger values within the ranges will normally be used where the social, economic, and environmental impacts are not critical." The *Green Book* also says that for rural and urban arterials, lane widths may vary from 10 to 12 feet. It goes on to say that 12-foot lanes should be used where practical on higher-speed, free flowing, principal arterials. However, under interrupted-flow conditions operating at low speeds (45 mph or less) narrower lane widths are normally quite adequate and have some advantages. Based on AASHTO guidelines, 10-foot lanes should therefore be considered the minimum standard. Yet, many states do not abide by their philosophy [21].

A survey was conducted on the current minimum travel lane width for each U.S. state. Ten of the states adhere to the *Green Book's* standards and another 10 states have 10-foot lanes as their minimum. Thirty states do not allow 10-foot lane widths (Table 2.2), despite it being an acceptable option within the *Green Book*.

Table 2.2: Minimum Travel Lane Width

Lane Width (feet)	Number of States using each Minimum Lane Width	Percent
12	6	12%
11	24	48%
10	10	20%
Green Book Standards	10	20%
Total	**50**	**100%**

The general perception is that the wider the lane, the greater the capacity and safety. According to the *Highway Capacity Manual*, lanes narrower than 12 feet reduce the capacity of a roadway. Streets with 11 foot lanes have 3% less capacity than streets with 12 foot lanes. Likewise, streets with 10 foot lanes have 7% less capacity than streets with 12 foot lanes; streets with 9 foot lanes have 10% less capacity than streets with 12 foot lanes [22]. Recent research may suggest that the lane width impact may not be as significant. In 2007, a literature search was performed as part of the Florida Department of Transportation *Conserve By Bike Program Study*. This literature search was conducted to evaluate findings of recent research from across the United States on the impacts to urban street capacity resulting from states using narrow lane widths. Researchers noted:

> *"The measured saturation flow rates are similar for lane widths between 10 feet and 12 feet. For lane widths below 10 feet, there is a measurable decrease in saturation flow rate. Thus, so long as all other geometric and traffic signalization conditions remain constant, there is no measurable decrease in urban street capacity when through lane widths are narrowed from 12 feet to 10 feet."*

Therefore, capacity may not be impacted until lane widths are reduced to less than 10 feet [23].

A study performed under NCHRP 330 *Effective Utilization of Street Width on Urban Arterials* states, "all projects evaluated during the study that consisted exclusively of lane widths of 10 feet or more resulted in accident rates that were either reduced or unchanged." It also recommends, "Where streets cannot be widened, highway agencies should give strong consideration to the use of 10 feet lanes where they are necessary as part of a geometric improvement to improve traffic operations or alleviate specific accident patterns." Likewise, the Midwest Research Center reported, "A safety evaluation of lane widths for arterial roadway segments found no indication, except in limited cases, that the use of narrower lanes increases crash frequencies. The lane width effects in the analyses conducted were generally either not statistically significant or indicated that narrower lanes were associated with lower rather than higher crash frequencies. There were limited exceptions to this general finding." Researchers also stated, "the research found three situations in which the observed lane width effect was inconsistent-increasing crash frequency with decreasing lane width in one state and the opposite effect in another state. These three situations are [23]:

- Lane widths of 10 feet or less on four-lane undivided arterials;
- Lane widths of 9 feet or less on four-lane divided arterials; and
- Lane width of 10 feet or less on approaches to four-leg STOP-controlled arterial intersections [23].

Because of the inconsistent findings mentioned previously, it should not be inferred that the use of narrower lanes must be avoided in these situations. Rather, it is recommended that narrower lane widths be used cautiously in these situations unless local experience indicates otherwise." Based upon the findings from NCHRP 330 and the Midwest Research Center, it appears that narrowing lanes to less than the "standard" 12-foot width may not degrade safety. Caution must still be taken along with engineering judgment to determine if the situation permits the use of narrower lane widths [23].

There are other benefits of narrowing lane widths. On the environmental side, narrower lanes means less pavement (asphalt or concrete), runoff, and land consumed. On the economic side, narrower lanes means smaller right-of-way costs, reduced costs for utility easements, reduced construction costs, and reduced environmental mitigation costs. By reducing lane widths and better providing for the mobility of all transportation systems users, fossil fuel use and emissions can be reduced through lesser vehicular use. On the social side, less driving typically means increased walking and bicycling that can promote active lifestyles, help combat the growing obesity epidemic, and contribute to healthier and more active communities [23].

2.4.2 "Road Diets"

Converting a four-lane undivided roadway into a three-lane cross-section is a relatively new concept, and is popularly referred to as a "road diet." The term "road diet" may also be used to refer to the conversion of a six-lane cross-section to a five-lane section with a two-way left-turn lane (TWLTL). The existing pavement area of the roadway is reallocated, most often by simply changing the pavement markings. Road diet conversion is particularly suitable for the sites where the existing roadway and pavement conditions are in acceptable condition. The additional pavement made available from the former lane may be used to provide additional lane width or be converted to bicycle lanes or on-street parking. A greater discussion of TWLTLs is provided within the next section [24].

2.4.3 Two-Way Left-Turn Lanes (TWLTLs)

Two-way left-turn lanes are generally retrofitted to existing roadway cross-sections by either condensing lanes to add the center left-turn lane or restriped to include the left-turn lane. It was found that when a TWLTL is added to the existing cross-section, the operational and safety features of a roadway are generally enhanced. Typical operational benefits are a decrease in delay and a reduction in the interactions during lane changes. Adding a TWLTL to the existing cross-section can lead to a decrease in the crash rates, especially at locations where parallel parking is allowed. At locations where parallel parking is not allowed, the reduction in crash rates may not be significant. A reduction of average arterial through-vehicle travel speed can be observed with an increase of heavy vehicles. Some communities have reported an increase in the pedestrian and bicycle activity as a three-lane cross-section can be easier to cross [25].

A decrease in the mean and 85th percentile speeds is often observed when a four-lane roadway is converted to a three-lane roadway. The decrease in the mean and 85th percentile speed is typically less than 5 miles per hour. Nearly all documented literature shows that a four-lane to three-lane conversion is accompanied with a reduction in crashes. Studies in Washington and California reported a reduction of 6 percent in crash frequency. Recent studies in Iowa have reported up to a 25 percent reduction in crash frequency. Although the exact percent of improvement varies, it is fairly consistent that safety improvements are achieved with four-lane to three-lane with TWLTL conversions [25].

A before-and-after analysis of nine sites in Minnesota, in which a four-lane roadway was converted to a three-lane TWLTL, was studied to determine if drivers may avoid these roadway types. Study results showed that the overall change in ADT was not statistically significant. There was no evidence to suggest that traffic diverted to other routes or that drivers changed travel behavior [25]. However, a significant change in speed was found even though the average speed reduction was approximately 2 miles per hour. This speed reduction may not be practically significant, but does suggest a slight increase in vehicle density as traffic is condensed from two to one through lane. Simple linear regression analysis showed that before-after mean speed reductions increased as both the density of unsignalized intersections increased and ADT increased. This result is consistent with the expectation that an increase in ADT will lead to more operational impacts with the four-lane to three-lane conversion. Average reduction in the 85th percentile speed after the conversion was consistent with the mean speed, with the average reduction in the 85th percentile speed approximately 1.7 mph. The speed of vehicles on a three-lane roadway with TWLTL after conversion from a four-lane roadway can be influenced by one of the three primary factors [25]:

- The speed of the vehicles on a three-lane roadway may increase because the left turning traffic is separated from the through traffic;
- The speed of the vehicles may decrease as right turning traffic and through traffic have to share a single lane; or
- Lastly, the speed of the vehicles may decrease due to the reduction of lane capacity associated with the removal of two center through lanes. Reduction in capacity leads to the increase in the flow density which in turn leads to a decrease in the speed [25].

A reduction in mean speed was observed at all study sites, which implies that the second and/or third factors had the greatest effect on speed after the conversions [25].

The change in crash frequency and the crash rates of the total crashes, injury crashes, and property damage only crashes were found to be statistically significant. After categorizing the crashes by type, only the change in the crash frequency for left-turn crashes and left-turn crash rates were found to be statistically significant. No change in rear-end crashes was likely due to the fact that right-turn traffic does not change significantly with the cross-section change. Some reduction in right-angle crashes was observed, but not at a statistically significant level [25].

To show how the results of a more robust statistical method would compare to the traditional approaches, a yoked/group comparison approach was explored. The percentage reductions in total crashes, property damage only (PDO) crashes, and left turn crashes after the conversion were approximately 37 percent, 46 percent, and 24 percent, respectively. Injury crashes were not found to be statistically significant, largely due to the increase in variance. Reductions in crash rate (per vehicle mile travelled) for total crashes and PDO crashes were also found to be statistically significant with reductions of approximately 47 percent and 45 percent, respectively [25].

Finally, the recommended approach for before-and-after statistical analysis of safety data is the Empirical Bayes approach which was outlined in the report. The results of the EB analysis showed an overall reduction in the total crash frequency of 44.2 percent, which was similar to crash reductions observed using traditional and yoked/group comparison statistical approaches. This similarity is important, because it validates the findings of the traditional and yoked/group comparison versus the highly accurate, yet difficult to perform, Empirical Bayes method [25].

Based on the research, four-lane to three-lane conversions can improve safety with little impact to operational conditions. It is recommended that four-lane to three-lane conversions be implemented after considering the following factors [25]:

- TWLTL use is suitable for locations where it is probable that the number of businesses along the roadway will be the same or increase with time. TWLTLs provide the advantage of separating the left-turning traffic out from the through lanes, providing better traffic flow compared to undivided four-lane sections without TWLTLs. The crash frequency on a roadway having a TWLTL is relatively insensitive to the number of accesses along the roadway, unlike four-lane divided and undivided roadways, which typically see increases in crashes as access density increases;
- Four-lane to three-lane conversions are feasible if the ADT of the roadway is less than 17,500 vpd. Although this ADT was approximately the maximum ADT observed in this research, and generated in a simulated research effort, observations made during this research support that additional consideration should be made when projected ADTs meet or exceed this value; and
- Four-lane to three-lane conversions were found to be effective in reducing the operating speeds and crashes of the roadway with little impact on capacity. Therefore, although a roadway cross-section change is not a countermeasure for speeding problems, some speed reduction benefits can be gained with this cross-section change [25].

Another analysis was performed on arterial roadway segments in Minnesota and Michigan. The roadway segments in Minnesota were mainly located in in the Minneapolis-St. Paul metropolitan area; study sites were chosen in both urban and suburban environments. The roadway segments in Michigan were located in Oakland County, a primarily suburban area in the northern portion of the Detroit metropolitan area. For the study, five different types of arterials were examined [26]:

- Two-lane undivided arterials;
- Three-lane arterials including a center TWLTL (two-way left-turn lane);
- Four-lane undivided arterials;
- Four-lane divided arterials; and
- Five-lane arterials including a center TWLTL [26].

The lane widths presented in Table 2.3 are the average lane widths across all through travel lanes at the study sites. The discussion here-on-forth will be analyzed with respect to the lane width category [26].

Table 2.3: Through Travel Lane Widths

Lane Width Category (feet)	Range of Lane Widths (feet)
9	9.5 or less
10	9.5 – 10.5
11	10.5 – 11.5
12	11.5 – 12.5
12	12.5 or more

Analysis of factors including roadway geometry, volume, and crash data showed that other than in a few cases, there was no statistically significant relationship between lane width and safety at midblock locations on arterials in urban and suburban settings. That is to say, none of the results showed that using 10 or 11 foot lanes as opposed to 12 foot lanes caused crash frequency to increase at midblock locations [26].

In some scenarios, using narrower lanes can lead to operational and safety benefits as well as "reduced interference with surrounding development" and more right-of-way for safety related improvements such as medians. Results of the analysis suggest that the aforementioned benefits can be obtained in many cases when narrow lanes are used without decreasing overall safety of the facility. However, for some facilities (e.g., those with high volumes of bicyclists where the bicyclists share the facility with motorists) designers should be cautious when using lanes under 12 feet in width [26].

The safety benefits for both researches are very similar to the findings discussed as part of the analysis of narrowed lanes in the earlier section in this report. The use of narrower lanes in appropriate locations can provide other benefits to users and the surrounding community, including shorter pedestrian crossing distances and space for additional through lanes, auxiliary and turning lanes, bicycle lanes, buffer areas between travel lanes and sidewalks, and placement of roadside hardware [26].

2.4.4 Bicycle Boulevards

Bicycle boulevards can be a very influential part of a roadway network. They can alleviate some of the motorized traffic in an area and provide bicyclists with an alternate facility on which to travel that can be categorized as a bicycle path, bicycle lanes, or a shared roadway. Whichever one of the three facilities chosen is heavily dependent upon the connectivity of the entire bicycle network along with the availability of right-of-way.

Bicycle boulevards (such as that seen in Figure 2.11) are facilities that fall under a low functional classification (e.g., local roads) and have applied strategies such installation of traffic calming treatments, installation of special signage and pavement markings, and installation of special crossings in order to provide an especially "bicycle-friendly" facility. These strategies are intended to provide a high degree of mobility for bicyclists in the area, while at the same time discouraging non-local drivers from using the facility as a way to cut through an area. Although use of the facility by some drivers may be discouraged, those that need to access property along the boulevard are still able to do so [27].

Bicycle facilities are commonly grouped into one of the three categories by engineers, planners, and bicyclists themselves [27]:

- Bicycle Path – Bicycle paths are physically separated from motor vehicle traffic and are commonly located beyond the right-of-way for the roadway itself. These paved facilities, such as multi-use paths, are often used by pedestrians and users of other non-motorized forms of transportation (e.g., skateboards, roller skates, etc.) in addition to bicyclists. In some cases, they are also used by equestrians;
- Bicycle Lane – Bicycle lanes are specially signed and marked areas within the right-of-way of the road for the exclusive use of bicyclists. These lanes operate in a one-way manner; and
- Shared Roadway – As the name implies, a shared roadway is a roadway that is designated for shared use by both bicyclists and motorists. On such facilities, bicyclists travel on a paved shoulder portion of the roadway or a widened outside lane adjacent to the curb. In some cases, these facilities have signs designating them as preferred bicycle routes [27].

Figure 2.11: Bicycle Boulevard Shared with Local Motorized Traffic [27]

Locations of bicycle boulevards are established based upon several criteria. One key consideration is the degree of access the route provides to important locations and trip generators as well as how direct this access is in terms of the route. Operational characteristics of the roadway, such as traffic speeds and volumes, in both the present time and in the future following the possible implementation of a traffic calming treatments and a bicycle boulevard are also of concern. Finally, sometimes terrain can be a concern if steep grades or other unusual geometric features are present [27].

Making sure that a bicycle boulevard integrates well with the existing transportation network in a given area is quite important as they are not intended to be isolated facilities. As such, the area's long-term transportation plan should be consulted and reviewed when considering potential bicycle boulevard sites and installations. This can also prove beneficial as the route's adequacy, in terms of being one that may discourage non-local motorist traffic from using it as a bypass, can also be evaluated prior to creation or designation of an actual bicycle boulevard. Ensuring the boulevard provides connectivity to major destinations in order to increase bicyclist mobility is also an important tenent of the planning process. In some sense, this can be accomplished if the facility integrates well with the existing transportation network in the area and adds more options for route choices, while at the same time increasing access. Poorly planned bicycle boulevards that do not provide direct access to key destinations (or at least travel near to them) are not desirable despite their potential recreational benefits [27].

2.5 Minnesota State-Aid Program

Two Minnesota Administrative Rules (8820.9920 Minimum Design Standards; Rural and Suburban Undivided; New or Reconstruction Projects and 8820.9936 Design Standards, Urban; New or Reconstruction Projects) framed the basis of the Complete Streets Report in Minnesota. Minnesota Administrative Rule 8820.9920 provides design standards for new or reconstruction projects for rural and suburban undivided roadways with respect to projected ADT. Minnesota Administrative Rule 8820.9936 provides design standards for new or reconstruction projects for urban roadways with respect to functional classification and/or projected ADT. The Complete Streets Report was completed in response to the legislative directive to the commissioner of transportation to report on the department's Complete Streets activities. It was also required to address three topics: State Aid variance process, plan implementation, and statutory barriers [28, 29].

2.5.1 8820.9920 Minimum Design Standards; Rural and Suburban Undivided; New or Reconstruction Projects

New or reconstruction projects for rural and suburban undivided roadways must meet or exceed the minimum dimensions indicated in the following design chart (Table 2.4) [28].

Table 2.4: Design Standards for New or Reconstruction Projects for Rural and Suburban Undivided Roadways with Respect to Projected ADT

Projected ADT (b) (veh/day)	Lane Width (feet)	Shoulder Width (g) (feet)	In-Slope (c) (rise: run)	Recovery Area (d) (feet)	Design Speed (e) (mph)	Surfacing	Structural Design Strength (h) (tons)	Bridges to Remain (f) Width Curb to Curb (feet)
0 – 49	11	1	1:3	7	30 – 60	Agg.		22
50 – 149	11	3	1:4	9	40 – 60	Agg.		22
150 – 749	12	4	1:4	15	40 – 60	Paved	9	28
750 – 1499	12	4	1:4	25	40 – 60	Paved	9	28
1500 and over	12	6 (g)	1:4	30	40 – 60	Paved	10	30

Engineering judgment may be used to choose a lane-width or shoulder-width dimension other than the widths indicated in the chart for roadways. Factors to consider may be safety, speed, population/land use, benefit/cost analysis, traffic mix, farm equipment, environmental impacts, terrain limitations, bicycle traffic, pedestrian traffic, other non-motorized uses, functional classification, or other factors. Widths less than those indicated in the chart require a variance in accordance with parts **8820.3300** and **8820.3400** [28]:

(a) For rural divided roadways, use the geometric design standards of the *MnDOT Road Design Manual*, with a minimum ten tons structural design and minimum 40 mph design speed.
(b) Use the existing traffic for highways not on the state-aid system;
(c) Applies to slope within recovery area only; and
(d) Obstacle-free area (measured from edge of traffic lane). Culverts with less than 30- inch vertical height allowed without protection in the recovery area [28].

For rural reconstruction projects, if the roadway is designated as a bicycle facility by the road authority, at least four feet of the shoulder shall be paved [28].

Guardrail is required to be installed at all bridges where the design speed exceeds 40 mph, and either the existing ADT exceeds 400 or the bridge clear width is less than the sum of the lane and shoulder widths. Mailbox supports must be in accordance with chapter 8818 [28].

For roadways in suburban areas as defined in part **8820.0100**, the recovery area may be reduced to a width of ten feet for projected ADT under 1,000 and to 20 feet for projected ADT of 1,000 or over. Wherever the legal posted speed limit is 40 mph or less, the recovery area may be reduced to a width of ten feet [28]:

(a) Subject to terrain. In suburban areas, the minimum design speed may be equal to the current legal posted speed where the legal posted speed is 30 mph or greater;
(b) Inventory rating of H 15 is required. A bridge narrower than these widths may remain in place if the bridge is not deficient structurally or hydraulically;
(c) Shoulders are required to be a minimum width of eight feet for highways classified as minor arterials and principal arterials with greater than 1,500 ADT projected, at least two feet of which must be paved; and
(d) Phased projects must be constructed to attain design strength within three years of completion of final grading. In suburban areas, the minimum structural design strength is nine tons or ten tons as needed for system continuity [28].

Approach side slopes must be 1:4 or flatter when the ADT exceeds 400. HS 25 loading with AASHTO Standard Specifications or HL-93 loading with load and resistance factor design (LRFD) is required for new or reconstructed bridges. HS 18 loading is required for all rehabilitated bridges. The curb-to-curb minimum width for new or reconstructed bridges must be no less than either the minimum required lane plus shoulder width or the proposed lane plus shoulder width, whichever is greater, but in no case less than the minimum lane widths plus four feet, and in no case less than required per Minnesota Statutes, section **165.04** [28].

For roundabout design, the design criteria of the current edition of the Minnesota State Aid Roundabout Guide are recommended [28].

2.5.2 8820.9936 Design Standards, Urban; New or Reconstruction Projects

New or reconstruction projects for urban roadways must meet or exceed the minimum dimensions indicated in the following design chart (Table 2.5) [29].

Table 2.5: Design Standards for New or Reconstruction Projects for Urban Roadways with Respect to Functional Classification and/or Projected ADT

Functional Classification and Projected Traffic Volume	**Design Speed** (mph)	**Lane Width** (a) (feet)	**Curb Reaction Distance** (e) (feet)	**Parking Lane Width** (feet)
Collectors or Locals with ADT < 10,000	30 – 40	11 (b)	2	8
	40 and over	12	2	10
Collectors or Locals with ADT ≥ 10,000 and Arterials	30 – 40	11 (b)	4 (c)	10
	40 and over	12	4 (c)	10 (d)

(a) One-way turn lanes must be at least ten feet wide, except 11 feet is required if the design speed is over 40 mph;
(b) Wherever possible, lane widths of 12 feet, rather than 11 feet, should be used;
(c) May be reduced to 2 feet if there are four or more traffic lanes and on one-way streets;
(d) No parking is allowed for six or more traffic lanes or when the posted speed limit exceeds 45 mph; and
(e) Curb reaction must be provided only where parking is not provided [29].

One-way streets must have at least two through-traffic lanes. When a median is included in the design of the two-way roadway, a 1-foot reaction distance to the median is required on either side of the median. Minimum median width is four feet [29].

Urban design roadways must be a minimum nine tons structure design, or ten tons if needed for system continuity. Phased projects must be constructed to attain design strength within three years of completion of final grading [29]. Roadways not on the state-aid system are not subject to the minimum structural design strength requirements [29].

Clearance of 1.5 feet from the face of the curb to fixed objects must be provided when the posted speed is 40 to 45 mph. A 10 foot clear recovery area measured from the driving lane must be provided when the posted speed exceeds 45 mph [29].

For volumes greater than 15,000 projected ADT, at least four through-traffic lanes are required. Additional average daily traffic may be allowed if a capacity analysis demonstrates that level of service D or better is achieved at the higher traffic volume. If the capacity analysis demonstrates that additional lanes are required only during peak traffic hours, then each additional driving lane may be used as a parking lane during nonpeak hours [29].

For roundabout design, the design criteria of the current edition of the Minnesota State Aid Roundabout Guide are recommended [29].

2.5.3 8820.9941 Minimum Design Standards: On-Roadway Bicycle Facility for Urban; New or Reconstruction Projects

If a road authority decides that a roadway will be designed to include an on-road bicycle facility, and only if the roadway is paved, the design standards in 8820.9941 apply [30].

Minimum design standards that must be met or exceeded by new or reconstruction projects for urban roadways can be seen in the following table [30].

Table 2.6: Design Standards for New or Reconstruction Projects on Urban Roadways

Functional Classification and Projected Traffic Volume	Design Speed (mph)	Lane Width (a) (feet)	Curb Reaction Distance (d) (feet)	Parking Lane Width (f) (feet)	Bikeway Design Roadways with Two Travel Lanes Urban Curb and Gutter (ADT)	(feet)	Bikeway Design Roadways with Four or more Travel Lanes Urban Curb and Gutter
Collectors or Locals with ADT < 2,000	25-30	10-12 (e)	2	7-10	< 500	SL	N/A
					500-2,000	WOL 14-16 or BL 5-6	
	35-40	11-12	2	8-10	< 500	SL	BL 5-6
					500-2,000	WOL 14-16 or BL 5-6	
	Over 40	12	2	10		BL 5-6	BL 5-6
Collectors or Locals with ADT 2,000-5,000	25-30	10-12 (e)	2	7-10		WOL 14-16 or BL 5-6	WOL 14-16 or BL 5-6
	35-40	11-12	2	8-10		BL 5-6	BL 5-6
	Over 40	12	2	10		BL 6	BL 6
Collectors or Locals with ADT 5,000-10,000	25-30	10-12 (e)	2	7-10		BL 5-6	BL 5-6
	35-40	11-12	2	8-10		BL 5-6	BL 5-6
	Over 40	12	2	10		BL 6 or PS 8 or SUP	BL 6 or PS 8 or SUP
Collectors or Locals with ADT > 10,000 and Arterials	30-40	11-12	4 (b)	10		BL 6 or PS 8 or SUP	BL 6 or PS 8 or SUP
	Over 40	12	4 (b)	10 (c)		BL 6 or PS 8 or SUP	PS 8 or SUP

(SL = shared lane; BL = bicycle lane; WOL = wide outside lane; PS = paved shoulder; SUP = shared use path)

(a) The minimum width of a one-way turn lane is 10 feet, except in cases when the design speed is greater than 40 mph, in which case it is 11 feet;
(b) A minimum curb reaction distance of two feet can be used if there are four or more traffic lanes and one-way streets;
(c) Parking is not allowed on streets with six or more traffic lanes or when posted speed is greater than 45 mph;
(d) Unless an on-street parking facility, a bicycle facility, or a wide outside curb lane are provided next to the curb, curb reaction distance must be provided. Wide outside lane dimensions include curb reaction distance;
(e) Multimodal designs including various vehicle lane, parking lane, and bikeway lane widths, with a vehicle lane width less than 11 feet must use parking and bikeway lanes a minimum of 1 foot wider than their minimum widths. Other factors to consider in such design scenarios include composition of the traffic (types of vehicles), park hour volumes, crash history/analysis, and snow storage, among others listed in 8820.9941;
(f) ADT on the roadway and vehicle mix must be taken into consideration when determining parking lane width for residential, commercial and/or industrial areas, or for a mixed use of such land-use categories [30].

If a width other than those shown in the table for lane-width, on-road bicycle facility, or shoulder width is desired, engineering judgment should be used. Some factors to consider that can help guide such choices are safety, speed, population/land use, environmental impacts, terrain limitations, bicycle traffic, and right-of-way constraints among others; additional considerations are outlined in 8820.9951. If dimensions less than those presented in the table are desired to be used on a facility, a variance aligned with the provisions in 8820.3300 and 8820.3400 is required [30].

A minimum of two through-traffic lanes is required on one-way streets. A one-foot reaction distance on each side of the median is also required when a raised median is part of the design of a two-way roadway. The minimum width for the median is four feet. Urban design roadways must accommodate at least a nine ton structural axle load design. In the case a roadway is not on the State-Aid system, it is not subject to the minimum structural design strength requirements [30].

Minimum bridge widths are also discussed in 8820.9941. Of importance is the part noting that when a new bridge approach roadway has bicycle and pedestrian accommodations, the new bridge width must provide for these non-motorized users, except in the case that they are accommodated otherwise [30].

When the posted speed is 40 to 45 mph, clearance of 1.5 feet from face of curb to any fixed objects must be provided. For scenarios in which posted speeds are greater than 45 mph, a 10 foot clear zone must be provided; the clear zone is measured from the edge of the driving lane [30].

When ADT is projected to exceed 15,000, a minimum of 4 through-traffic lanes are required, except if a capacity analysis shows that a different lane configuration attains a level of service no worse than D. 8820.9941 concludes with additional structural requirements for bridges and underpasses [30].

2.5.4 8820.9951 Minimum Design Standards, On-Road Bicycle Facilities for Urban; Reconditioning Projects

If a road authority decides that a roadway will be designed to include an on-road bicycle facility, and only if the roadway is paved, the design standards in 8820.9951 apply [31].

Minimum design standards that must be met or exceeded by reconditioning projects for urban roadways can be seen in the following table [31].

Table 2.7: Design Standards for Reconditioning Projects on Urban Roadways

Number of Through Lanes, Functional Class, and Present Traffic Volume	Design Speed (mph)	Lane Width (feet)	Parking Lane Width (e) (feet)	Proposed Structural Design Strength (tons)	Bikeway Design	
					(ADT)	(feet)
Two-Lane Collectors or Locals with ADT < 10,000	25-30	10-12 (d)	7-10	9 (b)	< 1,000	SL
					1,000-5,000	WOL 14-16 or BL 5-6
					5,000-10,000	BL 5-6
	35-40	11-12	8-10	9 (b)	< 500	SL or BL 5-6
					500-10,000	BL 5-6
	Over 40	11-12	10	9 (b)	< 10,000	BL 5-6
Two-Lane Collectors or Locals with ADT > 10,000 or Two-Lane Arterials (a)	25-30	10-12 (d)	7-10	9	> 10,000	BL 5-6
	35-40	11-12	8-10	9	> 10,000	BL 5-6 or PS 8
	Over 40	11-12	10	9	> 10,000	PS 8 or SUP
Four-Lane Collectors or Arterials with ADT < 10,000	25-30	10-12 (d)	7-10	9 (b)	< 10,000	WOL 14-16 or BL 5-6
	35-40	11-12	8-10	9 (b)	< 10,000	BL 5-6
	Over 40	11-12	10	9 (b)	< 10,000	BL 6
Four-Lane Collectors or Locals with ADT > 10,000	30-40	11-12	10	9	> 10,000	BL 6 or PS 8 or SUP
	Over 40	11-12	10	9	> 10,000	BL 6 or PS 8 or SUP

(a) A road may be reconditioned under this part if current ADT is less than 15,000;
(b) A seven-ton axle load structural design strength can be used if ADT is less than 5,000;
(c) Parking is not allowed on six-lane collectors or arterials;
(d) Multimodal designs including various vehicle lane, parking lane, and bikeway lane widths, with a vehicle lane width less than 11 feet must use parking and bikeway lanes a minimum of 1 foot wider than their minimum widths. Other factors to consider in such design scenarios include composition of the traffic (types of vehicles), park hour volumes, crash history/analysis, and snow storage, among others listed in 8820.9951;
(e) ADT on the roadway and vehicle mix must be taken into consideration when determining parking lane width for residential, commercial and/or industrial areas, or for a mixed use of such land-use categories [31].

If a width other than those shown in the table for lane-width, on-road bicycle facility, or shoulder width is desired, engineering judgment should be used. Some factors to consider that can help guide such choices are safety, speed, population/land use, environmental impacts, terrain limitations, bicycle traffic, and right-of-way constraints among others; additional considerations are outlined in 8820.9951. If dimensions less than those presented in the table are desired to be used on a facility, a variance aligned with the provisions in 8820.3300 and 8820.3400 is required [31].

Unless on-street parking, a bicycle facility, or a wide outside lane are provided next to the curb, curb reaction distance must be a minimum of one foot. Wide outside lane dimensions include the curb reaction distance. A one-foot reaction distance on each side of the median is also required when a raised median is part of the design of a two-way roadway. The minimum width for the median is four feet. Additional provisions about minimum bridge widths are also covered in 8820.9951 [31].

2.5.5 Complete Streets Report

The *Complete Streets Report* commissioned for the Minnesota Legislature and finalized in January 2011 by the Minnesota Department of Transportation was completed in response to the legislative directive to the commissioner of transportation to report on the department's Complete Streets activities. The report was required to address three topics: State Aid variance process, plan implementation, and statutory barriers [32].

2.5.5.1 State Aid Variance Process

The State Aid variance process is outlined in Minnesota Statute 162.155, 162.02, and 162.09. It notes that local agencies are able to receive waivers to Minnesota Rule 8820. The first step in doing so is to petition a variance committee. The variance committee then has the choice on whether or not to recommend the waiver to the commissioner of transportation, who can in turn choose whether or not to grant the request. As a result of the Complete Streets Legislation, variance committees must consider two main resources when hearing requests for waivers on issues involving complete streets; those two sources are *A Policy on Geometric Design of Highways and Streets*, from AASHTO and the *Context Sensitive Solutions in Designing Major Urban Thoroughfares for Walkable Communities*, from ITE [32]. There is a checklist to help complete a State Aid variance committee meeting, revised in August 2011. The detailed internal checklist helps State Aid staff to be knowledgeable of the steps required to process variance requests and to ensure that there is no loss of productivity as staff changes occur. The procedure described in the checklist helps preparers of the variance request to expedite the process and ensures they are fully informed and aware of their responsibilities. The checklist is as follows [33]:

1. As required by the State Aid Operations Rules: a certified resolution from the responsible city council or county board which identifies the project by location and termini, cites the applicable Rule and chapter, cites the standard for which the variance is requested, and describes what is proposed in lieu of the standard. If applicable, cite the relevant guidance provided in the latest edition of *A Policy on Geometric Design of Highways and Streets*, from AASHTO. For projects in urban areas, if applicable, cite the relevant guidance provided in the latest edition of the *Context Sensitive Solutions in Designing Major Urban Thoroughfares for Walkable Communities* from the ITE;
2. Location map and typical section (in-place and proposed);
3. Describe adjacent land uses (agricultural, residential, commercial, etc.);
4. Describe the needs of motorists, pedestrians, transit users, and vehicles, bicyclists, and commercial and emergency vehicles moving along and across roads, intersections, and crossings should be consideration in a manner that is sensitive to the local context. If applicable, cite the relevant guidance provided in the Institute of Transportation Engineers'

"Context Sensitive Solutions in Designing Major Urban Thoroughfares for Walkable Communities";
5. Describe effects of designing in accordance to Rule versus proposed non-standard element on adjacent properties, pedestrians, bicycles, motoring public, and emergency vehicles;
6. Define the critical design element involved (i.e., not "Design Speed"): horizontal alignment (radius or degree of curvature), vertical alignment, grades, lane width, shoulder width, bridge width, structural capacity, stopping sight distance (horizontal and vertical), cross slope, super-elevation, clearance (horizontal and vertical);
7. Estimate the cost/impacts to construct to the standard, the cost to build to the proposed element, and information that logically explains why the particular proposed design was chosen. For instance, if the radius and sight distance for a horizontal curvature is proposed at 35 mph instead of 55 mph, include cost/impacts for 50 mph and 40 mph radii and sight distance;
8. Include available crash data in detail that indicates the resulting damage (property damage/injury/death), contributing causes, and location.
   The Minnesota Crash Mapping Analysis Tool (MnCMAT) is available through the SALT Traffic Safety website at http://www.dot.state.mn.us/stateaid/sa_traffic_safety.html. Note that access to the MnCMAT application requires approval of the city or county engineer.
9. Include existing and projected traffic counts;
10. Include legal, posted, and/or safe speed of abutting roadway sections;
11. Indicate if future improvements are planned on the roadway or on adjacent property;
12. Describe safety mitigation considered, such as signing in accordance with Minnesota *MUTCD*, side-slop flattening, etc.; and
13. Any other pertinent factors [33].

From January 1 - October 1, 2010 four variance requests dealing with complete street designs were heard by variance committees, with three being approved. The request that was denied was from the City of Monticello; the City requested permission to narrow a Municipal State Aid Street with parking facilities on both sides of the roadway by two feet (from 38 feet to 36 feet). According to the variance committee, the request was denied for the following reasons [32]:

- "There is not a large parking demand. West River Street can remain 36 feet wide with parking allowed on one side or West River Street can be narrowed to 32 feet wide with parking allowed on one side of the street"; and
- "West River Street can be widened to 38 feet wide since there is sufficient right-of-way and there are few mature trees to remove" [32].

2.5.5.2 Plan Implementation

A webpage for Complete Streets has been created referencing off of the MnDOT website at http://www.dot.state.mn.us/planning/completestreets [34]. In an effort to implement the plan, MnDOT Staff members from various areas across the Department have been selected to discuss how to best implement a Complete Streets policy. According to the "Complete Streets Report", the following functional groups have been selected [33]:

- **Design Process** – The Design process group is working to outline numerous potential constraints during the design phase of a Complete Streets project. The group has held open discussions with MnDOT employees from various areas including Traffic, Design Standards, Maintenance and State Aid. Discussions have focused on design processes used by the Department and the key manuals such as the AASHTO *Green Book* and the Minnesota *MUTCD*. The group has since compared Minnesota State Aid standards with national standards and presented their findings to committees, at both the county and city level, that have the power to recommend proposed rule changes for Chapter 8820;

- **Funding and Planning** – This group is tasked with identifying best practices for planning and funding procedures pertinent to Complete Streets projects. They are working off a grant from the National Academies to develop and evaluate a Complete Streets planning process in Grand Rapids, MN. Further investigation of planning has arisen through a project by researchers at the University of Minnesota titled *Planning and Implementation of Complete Streets at Multiple Scales*. The proposed objective of the research project is to create a framework and guide to be used by transportation engineers, planners, and other industry workers for analyzing, evaluating, and in turn prioritizing transportation modes at important locations in a given area. The guide is projected to discuss successful planning of complete streets, present developing complete streets policies, and showcase project success stories with case studies of actual complete street implementations; and
- **Training and Support** – The focus of this group is to create training materials, procedures, etc. that can be used by local agencies to guide them through establishing Complete Streets policies. As was the case with the previous group, the University of Minnesota (specifically the Local Technical Assistance Program) will be involved in assisting this group with their mission. So far a *"Designing Complete Streets"* training program with "interactive exercises" has been implemented as a new component of MnDOT's Core Foundations Workshop. An additional part of the training program, called "*Serving All Modes*,*"* has been added to MnDOT's Advanced Flexibility in Design Workshop. At a basic level, the training modules discuss multi-modal transportation, the philosophy of complete streets, pros and cons of complete street designs, and ways to evaluate risk. Other topics covered include "universal design principles," ADA compliant designs, and meeting the needs of non-motorized and transit users in the transportation system [33].

2.5.5.3 Statutory Barriers

Besides the three aforementioned groups, an external advisory group was also created to discuss complete streets projects at a local level that align with MnDOT's Complete Streets goals. The group is composed of representatives from MnDOT as well as representatives from local agencies, stakeholder groups, federal agencies, and state government. So far, this group has identified three possible barriers to Complete Streets implementation at the local level. The group is hoping that these items be considered by the state legislature in the future although the time at which this may be done is uncertain. The three potential barriers are [33]:

- "Allow cities and counties with Complete Streets policies to be exempt from the requirement of Minnesota Statute 161, which requires a commissioner's speed study before establishing a speed limit other than the statutory defined limit";
- "Allow cities and counties with Complete Streets policies to be exempt from all State Aid design standards;" and
- "Waive the State Aid variance process requirement that requesting agencies assume all liability if the agency has adopted Complete Streets policies" [33].

Chapter 3: Stakeholder Correspondence

A stakeholder workshop for MnDOT Contract No. 89264, Work Order No. 7 was held in Room 2 at the MnDOT Training & Conference Center on August 25, 2011. A total of eighteen individuals were in attendance, representing the research team, departments of MnDOT, the Minnesota Complete Streets Coalition, the University of Minnesota, Hennepin and Kandiyohi Counties, and the cities of St. Paul and Minneapolis.

After individual introductions, the project background and scope was discussed. Additionally, the Minnesota statutory definition of complete streets was provided as "*The planning, scoping, design, implementation, operation, and maintenance of roads in order to reasonably address the safety and accessibility needs of users of all ages and abilities. Complete streets considers the needs of motorists, pedestrians, transit users and vehicles, bicyclists, and commercial and emergency vehicles moving along and across roads, intersections, and crossings in a manner that is sensitive to the local context and recognizes that the needs vary in urban, suburban, and rural settings*."

There were two main objectives of the workshop. The first was to identify locations where complete streets projects have been attempted or locations where complete streets projects should/could be attempted. The second was to develop a list of typical/common issues and concerns with the implementation of complete streets elements that lead to appropriate study variables.

Each objective was investigated by allowing the attendees to discuss into small groups (3-5 people) and develop ideas. The smaller groups reconvened and provided their ideas to the all attendees. The list of identified locations was as follows:

- W. 110th St, Bloomington, MN;
- 86th St, Bloomington, MN;
- Lexington Avenue (from Summit to Randolph), St. Paul, MN;
- Grand Avenue (Victoria Street area), St. Paul, MN;
- Lake Street (commercial district and parking), Hennepin County;
- Snelling Avenue (either side of I-94, especially north to 36th);
- Maryland Avenue (longest strip possible on either side of 35E);
- University Avenue (especially related to LRT and ADA compliance issues);
- Excelsior/County Road 3 (St. Louis Park area);
- East Washington Avenue (Madison, WI – as a comparison);
- Lindale Avenue/Hennepin County 22 (south of Lake to Minnehaha);
- Marshall Avenue, St. Paul, MN;
- Central Avenue (ID'ed by two groups);
- Highway 14 and Highland, New Ulm, MN;
- Nicollet Avenue;
- Como Avenue near University of Minnesota;
- Anything in downtown Minneapolis (especially as it relates to traffic coordination and multimodal users);
- Highway 169 in St. Peter (completed project);
- Grand Rapids (Mississippi River area);
- County Roads B1, B2, C in Roseville, MN;

- Trunk Highway 23;
- Highway 61;
- High Street Bridge (4% downgrade);
- Pelham at St. Anthony Parkway;
- Broadway, Alexandria, MN;
- Highway 14 in the Rochester, MN area;
- Radio Drive / Valley Creek Road;
- 76th Street, Richfield, MN;
- 70th Street, Edina, MN; and
- Highway 75, Breckinridge, MN.

The list of identified issues/concerns was as follows:

- Snow storage in the right-of-way;
- ADA compliance;
- Jurisdictional controls
  - Funding
  - Municipal consent (buy-in)
  - Inter-/Intra-departmental issues (projects that cross jurisdictional boundaries);
- AADT/L.O.S. issues when switching from 4-lane undivided to 3-lane (center TWLTL);
- R.O.W. constraints;
- Increased maintenance costs from plowing around road items;
- Parking vs. bicycle lanes;
- Medians/pedestrian refuges/signal timings:
  - Psychology of users; and
  - Feeling safe vs. actual safety;
- Staging of projects/programs to permit time for public input;
- Large vehicles (buses, trucks, etc.) on narrowed lanes;
- Balancing safety and capacity;
- Liability issues, especially as they relate to bikes and pedestrians;
- Bump-out conflicts with bicycle lanes;
- Sharrows (not currently permitted in MN);
- Complexity of context (reinforcement of driver behavior & driver expectancy);
- Conservative design (inclusion of a factor of safety):
  - Redundancy vs. cost effectiveness;
- Policy preferences for specific modes;
- Operational concerns for large vehicles;
- Adequate provision of parking (replacing lost parking, etc.);
- Balancing modes within existing R.O.W. (usage levels);
- Existing/future connections for project to pedestrian/bicycle networks;
- Casual vs. "serious" bicyclists (sidewalk/sidepath vs. lane usage);
- Obtaining proper documentation of decision-making process, especially for design exceptions, etc.; and
- Access points.

The results of the small group sessions, as evidenced by the preceding lists, were excellent. A good number of locations were identified, and a list of study variables to be considered with "complete streets" was developed. Following the meeting, the research team proceeded to work in conjunction with MnDOT staff to determine which locations would take priority for study purposes, and also to determine a rank order for the listed issues/concerns.

Chapter 4: Detailed Analysis of Selected Sites

4.1 Analysis Background

4.1.1 Purpose

This chapter describes in detail the process of data collection for case study sites and their safety evaluations using statistical methods from the *Highway Safety Manual*. The following sections present detail description of the study sites, the conditions before and after reconstruction, and safety evaluations of the improvements using both simple and Empirical Bayes (EB) before-after analysis. The results of safety evaluations are then compared with the geometric changes to establish qualitative and quantitative relationships between crash experiences and complete street improvements at each study site.

4.1.2 Site Selection

The process for selecting study sites consisted of gathering collective insight from industry professionals, as well as evaluating historical data to determine primary sites of success related to the Complete Streets concept within the state of Minnesota. A stakeholder workshop was held in August 2011 as described in Chapter 3. The main goal of the workshop was to develop lists of identified locations and evaluation topics based on the experiences of the attendees. The following nine sites were selected by consensus of the Technical Advisory Panel (TAP), MnDOT staff, and the research team:

1. Excelsior Boulevard (from Quentin Avenue South to Monterey Drive), St. Louis Park, MN;
2. Lyndale Avenue (from West 44th Street to West 34th Street), South Minneapolis, MN;
3. West 110th Street (from Normandale Boulevard to France Avenue), Bloomington, MN;
4. Lake Street (from 5th Avenue South to 22nd Avenue South), Minneapolis, MN;
5. 76th Street (from Xerxes Avenue South to South 12th Avenue), Richfield, MN;
6. TH 14 (Intersection of TH 14 and Highland Avenue), New Ulm, MN;
7. TH 169 (from TH 22 to Union Street), St. Peter, MN;
8. Hennepin / 1st Avenues (from 8th Street North to North Washington Avenue), Minneapolis, MN; and
9. Williamson Street (from South Blount Street to South Baldwin Street), Madison, WI.

After proceeding with these sites, it was later determine that two additional sites were necessary to more comprehensively capture new roadway cross-sections that specifically addressed bicycle lanes and facilities. After careful consideration, two additional study sites were proposed:

10. Marshall Avenue (from East Lake Street to Cretin Avenue South), St. Paul, MN; and
11. Franklin Avenue (from Riverside Avenue to 27th Avenue Southeast), Minneapolis, MN.

4.1.3 Data Collection

Data collected for each of these sites was quantitative and/or qualitative in nature, and is detailed in the section dedicated to that site in this report. Quantitative data collected primarily consists of speed, volume, vehicle classifications, crashes (if any), roadway geometrics, functional classification, access points, parking, surrounding land use, pedestrian access, and bus frequency and stop locations (if any). Through field observations, qualitative data collected may consist of: traffic flow and operations, effect of parking maneuvers (if any), "near misses", pedestrian and non-motorized vehicle behaviors, and driver behavior in mixed-modal flows including bus, truck, car, bicycle, and pedestrian interactions.

4.1.4 Safety Evaluation Methodology

Safety evaluations of each study site using crash data before and after reconstruction work was completed in order to determine the effects of various geometric changes. Crash data was broken into the following types of analyses:

1. Multiple vehicle crashes;
2. Single vehicle crashes;
3. Crashes by severity;
4. Bicycle and Pedestrian Crashes; and
5. Total crashes.

Two methods were used for safety evaluations namely simple before-after and Empirical Bayes (EB) before-after crash data analysis. The two methods were selected in view of the data available and the range of reconstruction work at each study site. A brief description of the two methods is provided here. Detailed steps and discussion is available in Chapter 12 of the HSM which pertains to urban and suburban arterials [35]. All study sites with the exception of 1 were urban/suburban arterials.

4.1.4.1 Simple Before-After Analysis

Simple before-after analysis of crash data consists of calculating the percentage difference between the crashes in the before and after period with the exception of the construction before as shown in the following equation.

$$\%\, Difference = (A - B)/B * 100$$

where,

% Difference = percent increase or decrease in the number of crashes,

A = number of crashes per year in the after period, and

B = number of crashes per year in the before period.

One of the disadvantages of using simple before-after methodology is the issue of regression-to-the-mean effect details of which can be found in the literature [35]. The use of EB methods for before-after crash analysis is recommended in order to account for the regression-to-the-mean effect and conduct realistic safety analysis.

4.1.4.2 Empirical Bayes Before-After Analysis

The EB methodology for before-after crash analysis accounts for the regression-to-the-mean effect by using data from similar sites. Crash analysis using EB can be conducted in a number of ways dependent upon data availability and other conditions. The methodology used in this report makes use of Safety Performance Functions (SPFs) and steps from the Highway Safety Manual (HSM).

The before-after analysis using EB methodology calculates the expected crash frequency in the after period (crashes which would have occurred had no construction been done) which is compared with the observed crash frequency in the after period. The expected crash frequency is a weighted sum of predicted (from SPF) and observed crashes (crashes in the before period) carried over to the after period. The difference between the expected and observed crashes in the after period is the increase or decrease in crashes without the regression-to-the-mean effect.

The most important aspect of EB analysis is the calculation of predicted crashes in the after period. For urban/suburban arterial segments, the HSM describes a detailed methodology to calculate the predicted crashes using separate SPFs for multiple-vehicle, single vehicle, and driveway-related crashes. Separate SPFs are also used for fatal/injury (FI) and property damage only (PDO) crashes. Additional steps were developed and used in this analysis to breakdown the predicted crashes into the following multiple vehicle crash types:

1. Rear-end crashes;
2. Head-on crashes;
3. Angle crashes;
4. Sideswipe-same direction crashes;
5. Sideswipe-opposite direction crashes; and
6. Other multiple-vehicle crashes.

Single vehicle crash types calculated in this report were of the following types:

1. Animal crashes;
2. Fixed object crashes;
3. Other object crashes; and
4. Other single vehicle crashes.

Bicycle and pedestrian crashes were identified but excluded from EB analysis because no SPF was available for them. The HSM provides some fixed proportion values to predict the number of bicycle and pedestrian crashes, but those values were not used in this analysis as it was difficult to establish their relevance to specific study sites used in this report.

The HSM describes the methodology for conducting EB analysis and provides "national" SPFs. Ideally, the SPFs from HSM should be calibrated for each individual state. However that requires obtaining and analyzing crash data for at least 30, preferably 100 sites of a specific type (four-lane undivided, two-lane undivided, etc.) which were not available for this analysis. Therefore, the SPFs from HSM were used without calibration.

Summary results of the simple and EB before-after crash analysis are presented in a single table for each site in respective sections in this report. Detailed analysis calculations and steps are presented in Appendix A. A one page summary of the site description, construction work completed, and the resulting effects on safety, in view of the before-after analysis for each site, is presented in Appendix B.

4.1.5 Assumptions / Limitations

As in all crash-based safety analyses, there are limitations to the analyses as well as required assumptions, both of which are described here. Ideally, at least 2 years of before and after crash data should be used for any before-after analysis. However, in some cases the number of years of crash data available was less. Therefore, caution should be used in interpreting and using the results of study sites where less than 2 years of crash data was available or where the number of crashes for a specific type was less than 0.5 crashes per year. Crashes at intersections which were identified from the crash data as not intersection-related were used in the analysis. However, crashes that were intersection-related were not analyzed in this report. The reason for not including these crashes was because most of the roadway reconstruction work was related to segment improvements such as lane width changes, lane reductions, median construction, bicycle lanes, and related geometry.

In most cases, the before and after periods were unequal, therefore, number of crashes per year were calculated to normalize for the difference which is why the results show number of crashes in decimal numbers. In some cases, segment conditions were generalized for the entire study site, e.g., if a segment section was comprised of 4 blocks and there was parking available for 3 blocks, it was assumed that parking was available for the entire section. The assumption would only affect the use of Crash Modification Factors (CMF) in calculating the predicted number of crashes using EB analysis. In cases where the number of years of crash data was less than one or where the proportions of crash types could not be effectively calculated based on the available data, default crash type proportion from the HSM were used. Although traffic volume information was available for all the sites, bicycle and pedestrian count information was not available. Therefore, caution should be used in analyzing the results of bicycle and pedestrian crashes between the before and after periods especially at sites where bicycle lanes were introduced which could result in an increase in bicycle traffic after reconstruction work thereby increasing exposure and the possibility of such crashes.

4.2 Detailed Analysis of Selected Sites

4.2.1 Excelsior Boulevard (Quentin Ave. S. to Monterey Dr.), St. Louis Park, MN (Hennepin County)

The section of Excelsior Boulevard between Quentin Avenue and Monterey Drive (shown in Figure 4.1) is 0.35 mile long and classified as a minor arterial. Along the boulevard are numerous shops and restaurants, as well as apartments, some of which are housed in the same buildings as the commercial properties. Several off-street parking lots are accessible from driveways along the corridor. The posted speed limit is 35 miles per hour and Metro Transit has four bus stops within the segment.

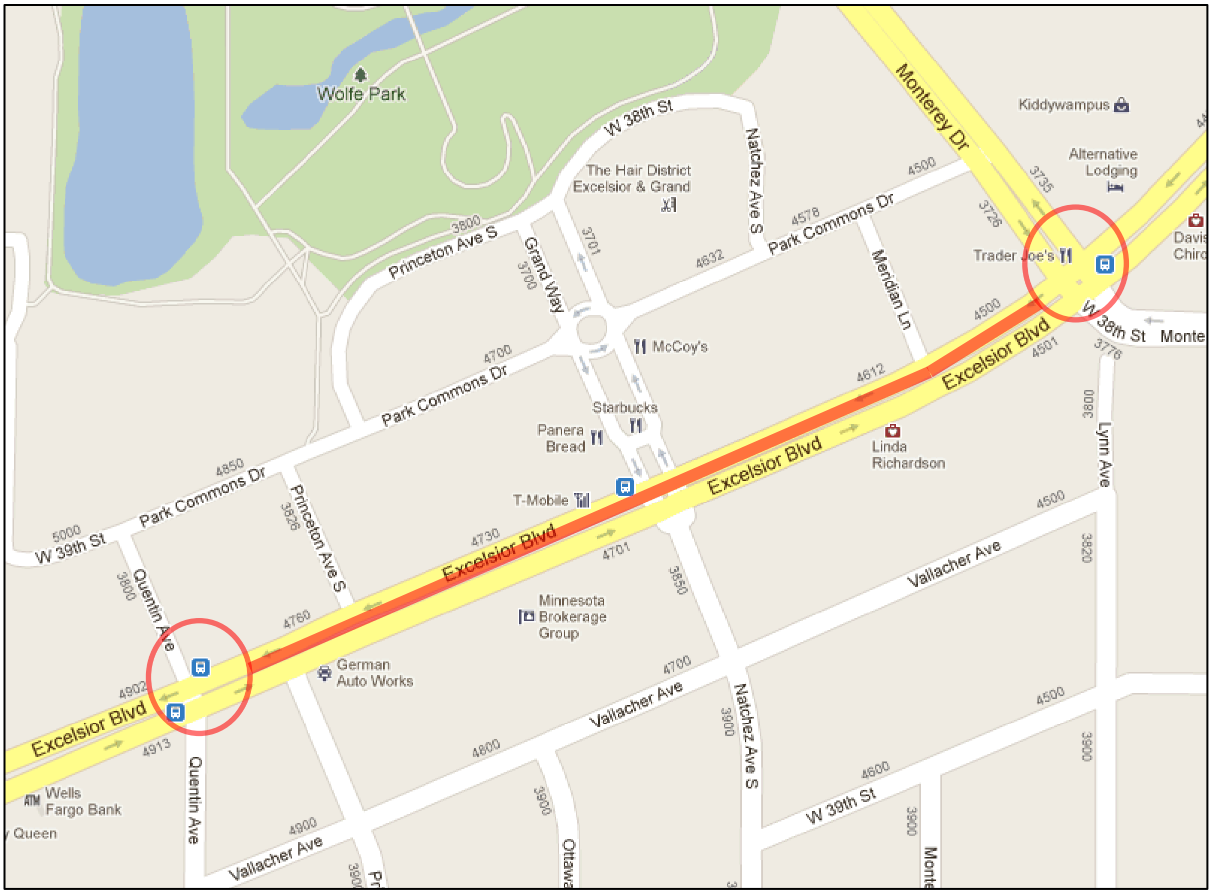

Figure 4.1: Excelsior Boulevard Study Area

Source: Google Maps. http://www.google.com/maps (Accessed 12 July, 2012).

4.2.1.1 Conditions Before and After Reconstruction

The existing roadway was previously a four-lane divided highway with sidewalks on both sides. From 2002-2003 reconstruction work was performed including repaving, landscaping, installing new curb and gutter, and other various improvements. Installation of new curb and gutter led to an increase in the width of the sidewalk on both sides of the road. Additionally, the width of the median increased on one side and decreased on the other due to the installation of the new curb and gutter section. There are two through lanes in each direction which vary in width from 11 to 12 feet. Auxiliary right turn lanes were added at the intersections of Excelsior Boulevard with Quentin Avenue, Grand Way, and Monterey Drive. Additionally, indented 10 feet parking bays were added to accommodate on-street parking. Pedestrian facilities include vast sidewalk areas ranging in width from 10 feet to 15 feet, including the width of the terrace. Although bicycle lanes were not included in the final design of this facility, streets running parallel to Excelsior Boulevard provide adequate accommodation for cyclists in the area.

Figures 4.2 and 4.3 show Excelsior Boulevard after reconstruction to highlight the changes in the cross-section. No figure was available to illustrate conditions before reconstruction.

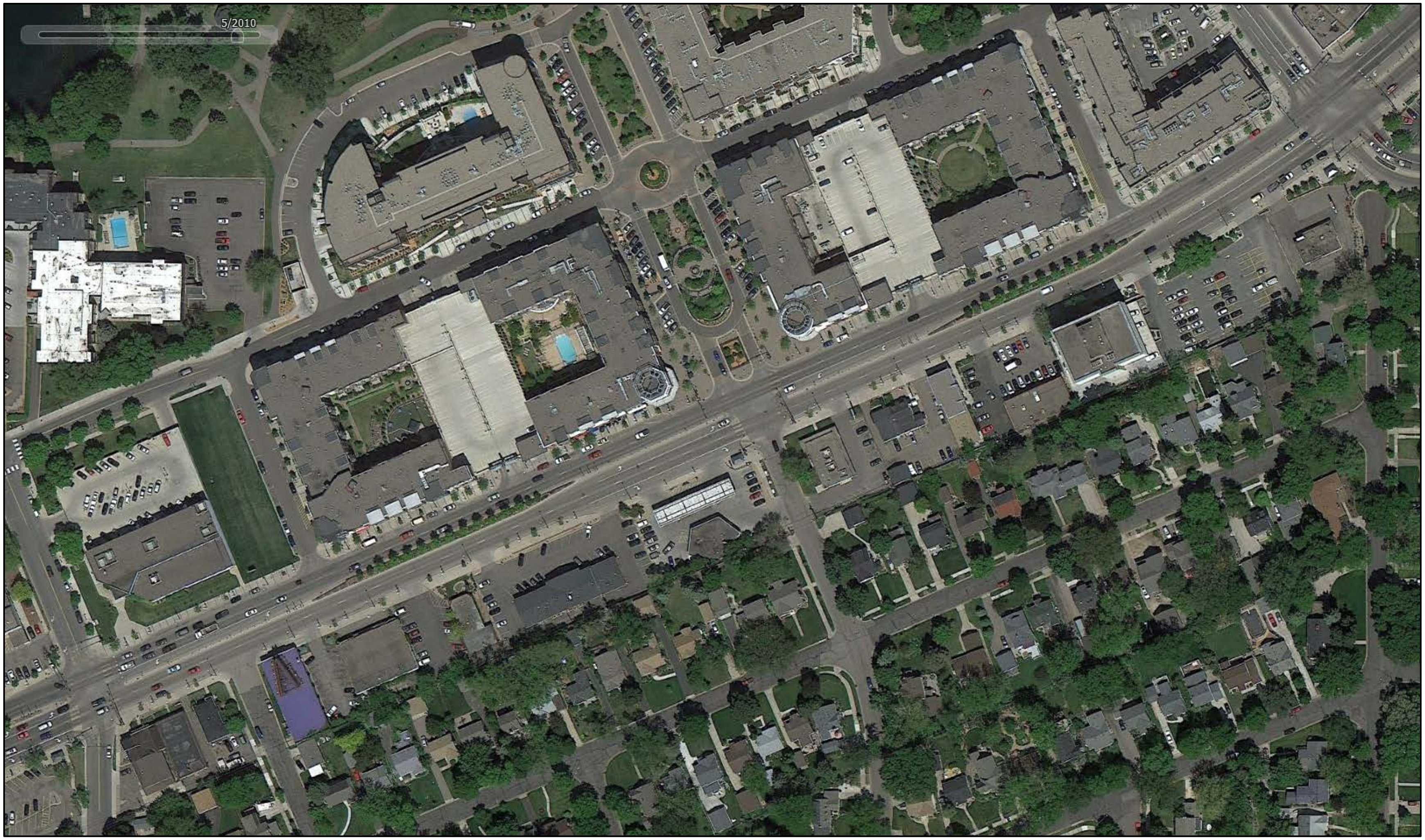

Figure 4.2: Excelsior Boulevard After Reconstruction

Source: Google Earth 6.2.2.6613. (18 May, 2010). Excelsior Boulevard 93°20'23.984"W, 44°56'0.1"N, Elevation 2633 ft. http://www.google.com/earth/index.html (Accessed 12 July, 2012).

Figure 4.3: Excelsior Boulevard and Grand Way Intersection After Reconstruction
Source: Google Earth 6.2.2.6613. (October, 2009). Excelsior Boulevard 93°20'23.984"W, 44°56'0.1"N, Elevation 914 ft. http://www.google.com/earth/index.html (Accessed 12 July, 2012).

4.2.1.2 Crash Data Analysis

Safety evaluation of reconstruction work at Excelsior Boulevard was conducted using 2.8 and 2.2 years of before and after crash data, respectively. Table 4.1 presents data on average annual daily traffic (AADT) and total number of crashes at the site in periods prior to and after the reconstruction. Detailed before-after crash analysis results using simple and EB methods is presented in Table 4.2.

Table 4.1: Crash Data for Excelsior Boulevard Study Area

Excelsior Boulevard		
	Before (1999-2001)	After (2004-2006)
	2.8 years	2.2 years
Segment Length	0.352 mile	
ADT	19,900 (2000)	20,000
Speed Limit	35 MPH	35 MPH
Total Crashes	29	20
FI	5	7
PDO	24	13
Rear-end	21	16
Head-on	0	0
Angle	3	0
Sideswipe, same direction	2	0
Sideswipe, opposite direction	2	0
Driveway-related	0	0
Other multiple-vehicle	0	0
Collision with animal	0	0
Collision with fixed object	1	4
Collision with other object	0	0
Other single-vehicle	0	0
Bicycle Crashes	1	1
Pedestrian Crashes	0	2

The results of simple before-after and EB analysis of crash types shows a general decrease in the number of crashes after reconstruction with the exception of an increase in single vehicle fixed object crashes. The results of simple before-after analysis of crash severity shows a decrease in PDO crashes but an increase in FI crashes. However, the result of EB analysis shows a slight decrease in FI crashes indicating a possible regression to the mean effect.

Although the result of simple before-after analysis of pedestrian crashes shows an increase, there were only two pedestrian crashes in the after period as compared to none before. Therefore, it is difficult to ascertain the exact safety impact of construction on pedestrian and bicycle safety. Overall, the results show that the improvements made at this section of Excelsior Boulevard were able to reduce the number and severity of crashes of vehicle crashes without any apparent adverse effects.

Table 4.2: Summary Results of Simple and EB Before-After Crash Analysis - Excelsior Boulevard

Before-After Analysis by Crash Type

Crash Type	Simple Before-After Analysis: Observed Crashes - Before Period (per year)	Simple Before-After Analysis: Observed Crashes - After Period with Treatment (per year)	Simple Before-After Analysis: Percent Change (%)	Empirical Bayes Analysis: Expected Average Crashes - After Period W/O Treatment (Per Year)	Empirical Bayes Analysis: Crashes Reduced (or increased) in After Period (Expected - Observed)	Empirical Bayes Analysis: Percent Change using Expected Average Crashes - After Period W/O Treatment Compared with Observed Crashes - After Period with Treatment (%)
When interpreting the results, caution should be used when crashes per year are less than 0.5 or less than 2 year of crash data is available						
Multiple Vehicles						
Rear End	7.4	7.1	**-4.0**	7.3	0.2	**-2.3**
Head On	0.0	0.0	**0.0**	0.0	0.0	**0.0**
Angle	1.1	0.0	**-100.0**	0.9	0.9	**-100.0**
Sideswipe - Same Direction	0.7	0.0	**-100.0**	0.5	0.5	**-100.0**
Sideswipe Opposite Direction	0.7	0.0	**-100.0**	0.5	0.5	**-100.0**
Other Multiple Vehicle	0.0	0.0	**0.0**	0.0	0.0	**0.0**
Driveway Related	0.0	0.0	**0.0**	0.6	0.6	**-100.0**
Single Vehicle						
Animal Crash	0.0	0.0	**0.0**	0.1	0.1	**-100.0**
Fixed Object Crash	0.4	1.8	**403.8**	0.7	-1.1	**156.1**
Other Object Crash	0.0	0.0	**0.0**	0.0	0.0	**-100.0**
Other Single Vehicle Crash	0.0	0.0	**0.0**	0.2	0.2	**-100.0**
Total	10.2	8.9	**-13.1**	10.6	1.7	**-16.2**

Before-After Analysis by Crash Severity

Crash Severity	Simple Before-After Analysis: Observed Crashes - Before Period (per year)	Simple Before-After Analysis: Observed Crashes - After Period with Treatment (per year)	Simple Before-After Analysis: Percent Change (%)	Empirical Bayes Analysis: Expected Average Crashes - After Period W/O Treatment (Per Year)	Empirical Bayes Analysis: Crashes Reduced (or increased) in After Period (Expected - Observed)	Empirical Bayes Analysis: Percent Change using Expected Average Crashes - After Period W/O Treatment Compared with Observed Crashes - After Period with Treatment (%)
FI	1.8	2.7	**51.1**	2.8	0.2	**-5.7**
PDO	8.5	4.4	**-47.5**	7.8	3.3	**-42.9**
Total	10.2	7.1	**-30.5**	10.6	3.5	**-33.0**

Simple Before-After Analysis - Bike and Pedestrian Crashes Only

Crash Type	Observed Crashes - Before Period (per year)	Observed Crashes - After Period with Treatment (per year)	Percent Change (%)
Bike Crashes	0.35	0.44	**25.9**
Pedestrian Crashes	0.00	0.89	**100.0**
Grand Total	0.35	1.33	**277.8**

4.2.2 Lyndale Avenue (W. 44th St. to W. 34th St.), South Minneapolis, MN (Hennepin County)

This site on Lyndale Avenue which is classified as a minor arterial spans 1.3 miles between West 44th Street and West 34th Street (area shown in Figure 4.4). Access to residences is granted via driveways and back-alley roads located to the East and West of Lyndale, respectively; access via the alleys, however, is more common. The speed limit in this primarily residential area is 30 miles per hour. Metro Transit has only one stop in the study area at the intersection of Lyndale Avenue and W. 38th Street.

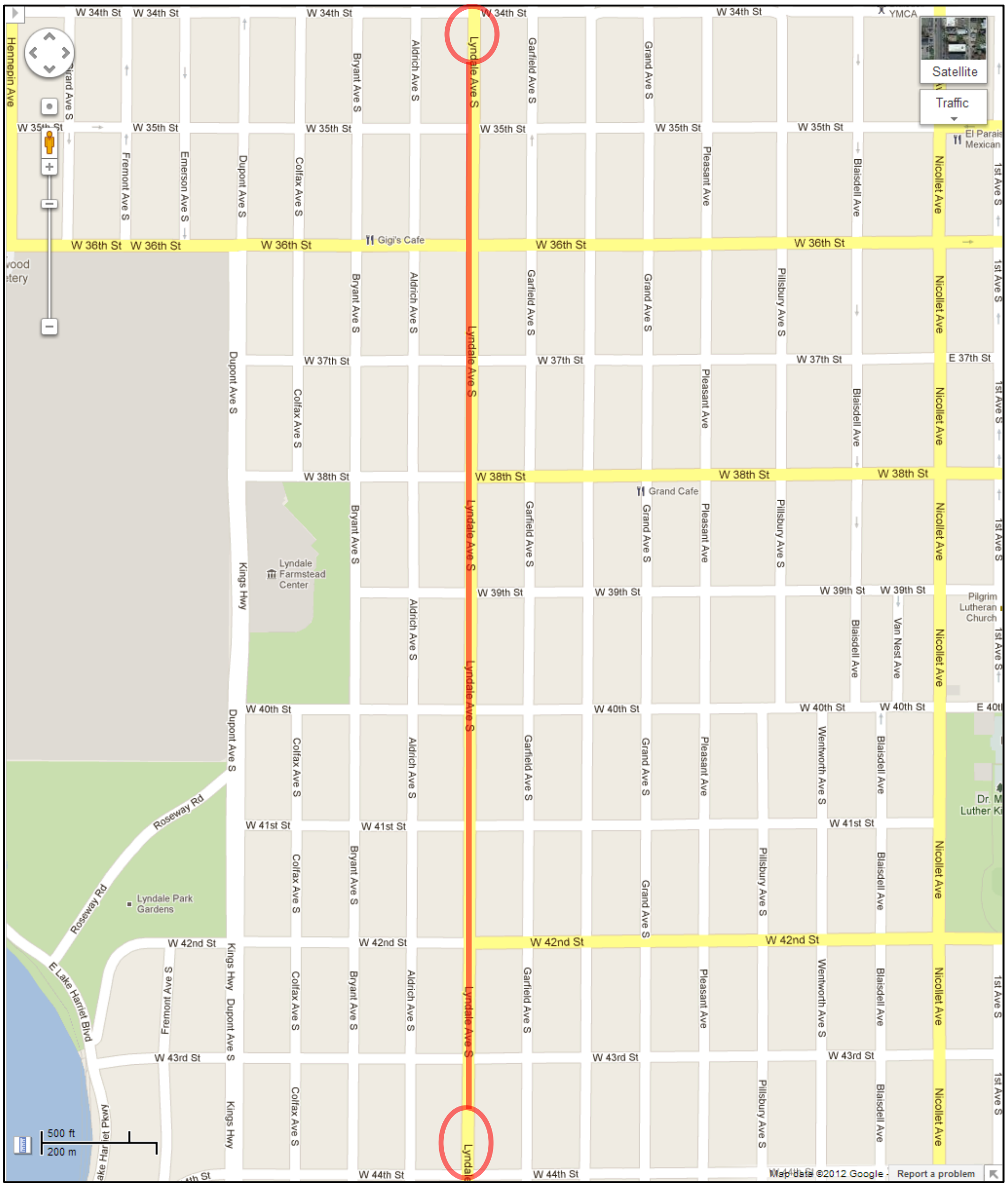

Figure 4.4: Lyndale Avenue Study Area

Source: Google Maps. http://www.google.com/maps (Accessed 12 July, 2012).

4.2.2.1 Conditions Before and After Reconstruction

Before reconstruction, Lyndale Avenue was a four-lane roadway with curb parking allowed during off-peak hours. There were no exclusive left-turn lanes or raised medians. After reconstruction in 2008-2009, Lyndale Avenue had two through lanes and two parking lanes. Many changes were made to the cross-section with respect to lane width, addition of a median, delineation of parking lanes, and addition of dedicated left-turn lanes. Excluding intersections, the cross-section between West 44th Street and West 34th Street consists of one 11 foot through lane and a 9 foot parking lane in each direction. Between West 38th Street and West 34th Street, a 10 foot wide raised median was incorporated and the through and parking lanes are 12 and 10 feet, respectively. Parking lanes were delineated following reconstruction in order to enhance their separation from travel lanes. In an attempt to augment capacity, an exclusive 11 foot left-turn lane was added at intersections in the segment between West 44th Street and West 39th Street. Similarly, between West 38th Street and West 34th Street, a 12 foot exclusive left-turn lane was incorporated into the intersections. Pedestrian accommodations, which remained unchanged after reconstruction, include sidewalks on both sides of the road separated from traffic by a terrace section ranging in width from 10 to 18 feet. No bicycle lanes were presented either before or after reconstruction at this site.

Figures 4.5 and 4.6 show the conditions before and after reconstruction on Lyndale Avenue between 36th and 37th street, highlighting the addition of a raised median, delineated parking, and exclusive left-turn lanes.

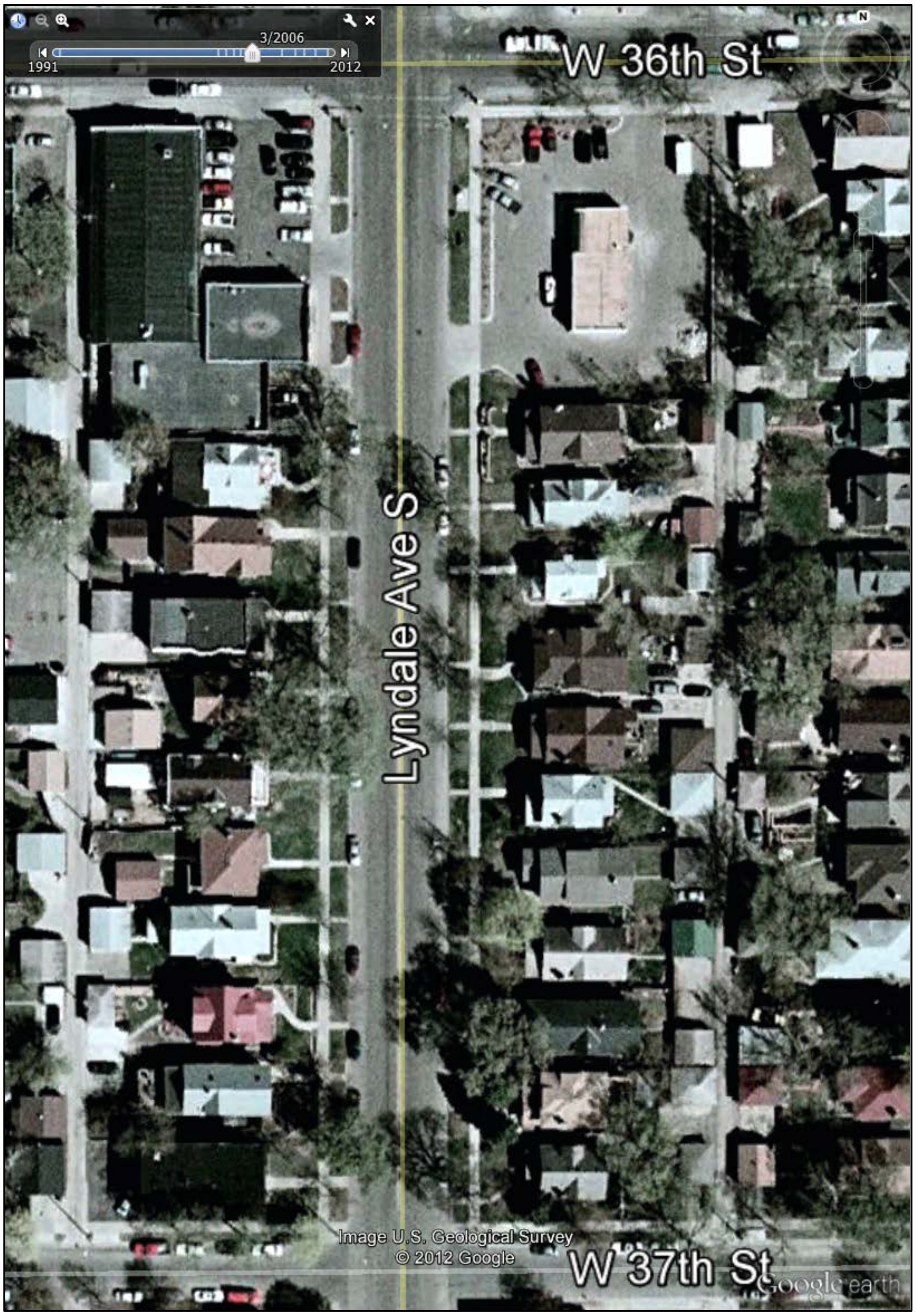

Figure 4.5: Example of Lyndale Avenue (36th and 37th street block) Before Reconstruction
Source: Google Earth 6.2.2.6613. (March, 2006). Lyndale Avenue 93°17'17.63"W, 44°56'12.50"N, Elevation 1302 ft. http://www.google.com/earth/index.html (Accessed 12 July, 2012).

Figure 4.6: Example of Lyndale Avenue (36th and 37th Street Block) After Reconstruction Showing Raised Median, Delineated Parking Lanes, and Exclusive Left-Turn Lanes

Source: Google Earth 6.2.2.6613. (May, 2010). Lyndale Avenue 93°17'17.63"W, 44°56'12.50"N, Elevation 1302 ft. http://www.google.com/earth/index.html (Accessed 12 July, 2012).

4.2.2.2 Crash Data Analysis

Safety evaluation of reconstruction work at Lyndale Avenue was conducted using 3.4 and 2.3 years of before and after crash data, respectively. Table 4.3 presents data on AADT and total number of crashes at the site in periods prior to and after the reconstruction. Detailed before-after crash analysis results using simple and EB methods is presented in Table 4.4.

Table 4.3: Crash Data for Lyndale Avenue Study Area

Lyndale Avenue (W 44th St to W 34th St)		
	Before (2004) (Crashes 2006 - May 2008)	After 2009 (Crashes Dec 2009 - 2012)
	3.4 years	2.3 years
Segment Length	1.3 Miles	
ADT	12,200 – 14,400	13,600 – 14,600
Speed Limit	30 MPH	30 MPH
Total Crashes	94	34
FI	27	11
PDO	67	23
Rear-end	29	9
Head-on	2	1
Angle	23	7
Sideswipe, same direction	13	7
Sideswipe, opposite direction	0	1
Driveway-related	1	1
Other multiple-vehicle	10	4
Collision with animal	3	1
Collision with fixed object	1	2
Collision with other object	10	1
Other single-vehicle	1	0
Bicycle Crashes	2	1
Pedestrian Crashes	4	1

The results of the simple before-after analysis of crash types show a general decrease in the number of crashes after reconstruction. Although the results show an increase in percentage of sideswipe opposite direction crashes, it is difficult to ascertain the significance of the results since the number of crashes increased by less than 0.5 crashes per year. Although fixed object crashes show an increase in the after period, overall the total number of crashes have been reduced in the after period. The results of simple before-after and EB analysis of crash severity show a decrease in severity of crashes.

Bicycle and pedestrian crashes were shown to have decreased via the simple before-after analysis of bicycle and pedestrian crashes; this decrease could be attributed to the construction of the median and lane delineation and markings improvements. Overall, the results suggest that the changes relative to the State Aid Design Standards in terms of reducing lane width and providing parking lanes did not reduce safety at this location. Rather, the total number of crashes was reduced. Some concerns were raised with regards to winter maintenance, e.g., snow plowing difficulties in areas of curb extensions.

Table 4.4: Summary Results of Simple and EB Before-After Crash Analysis - Lyndale Avenue

Before-After Analysis by Crash Type

	Simple Before-After Analysis			Empirical Bayes Analysis		
Crash Type	Observed Crashes - Before Period (per year)	Observed Crashes - After Period with Treatment (per year)	Percent Change (%)	Expected Average Crashes - After Period W/O Treatment (Per Year)	Crashes Reduced (or increased) in After Period (Expected - Observed)	Percent Change using Expected Average Crashes - After Period W/O Treatment Compared with Observed Crashes - After Period with Treatment (%)
When interpreting the results, caution should be used when crashes per year are less than 0.5 or less than 2 year of crash data is available						
Multiple Vehicles						
Rear End	8.5	3.9	**-54.6**	8.1	4.2	**-52.1**
Head On	0.6	0.4	**-26.8**	0.3	-0.2	**66.1**
Angle	6.7	3.0	**-55.4**	6.1	3.1	**-50.5**
Sideswipe - Same Direction	3.8	3.0	**-21.2**	2.9	-0.1	**3.1**
Sideswipe Opposite Direction	0.0	0.4	**100.0**	0.0	-0.4	**100.0**
Other Multiple Vehicle	2.9	1.7	**-41.4**	2.1	0.3	**-16.7**
Driveway Related	0.6	0.4	**-26.8**	1.8	1.3	**-75.5**
Single Vehicle						
Animal Crash	0.9	0.4	**-51.2**	0.4	0.0	**-3.5**
Fixed Object Crash	0.3	0.9	**192.8**	0.3	-0.6	**200.2**
Other Object Crash	2.9	0.4	**-85.4**	3.1	2.6	**-86.0**
Other Single Vehicle Crash	0.3	0.0	**-100.0**	0.3	0.3	**-100.0**
Total	27.5	14.6	**-47.0**	25.2	10.6	**-42.1**

Before-After Analysis by Crash Severity

	Simple Before-After Analysis			Empirical Bayes Analysis		
Crash Severity	Observed Crashes - Before Period (per year)	Observed Crashes - After Period with Treatment (per year)	Percent Change (%)	Expected Average Crashes - After Period W/O Treatment (Per Year)	Crashes Reduced (or increased) in After Period (Expected - Observed)	Percent Change using Expected Average Crashes - After Period W/O Treatment Compared with Observed Crashes - After Period with Treatment (%)
FI	7.9	4.7	**-40.3**	7.2	2.5	**-34.4**
PDO	19.6	9.9	**-49.7**	18.0	8.1	**-45.2**
Total	27.5	14.6	**-47.0**	25.2	10.6	**-42.1**

Simple Before-After Analysis - Bike and Pedestrian Crashes Only

Crash Type	Observed Crashes - Before Period (per year)	Observed Crashes - After Period with Treatment (per year)	Percent Change (%)
Bike Crashes	0.59	0.43	**-26.8**
Pedestrian Crashes	1.17	0.43	**-63.4**
Grand Total	1.76	0.86	**-51.2**

4.2.3 West 110th Street (Normandale Blvd. to France Ave.), Bloomington, MN

The segment of West 110th Street from Normandale Boulevard to France Avenue South (shown in Figure 4.7) is 1 mile in length. It is classified as a collector roadway and further designated as a Minnesota State Aid (MSA) Route. It travels through a residential area with numerous driveways on each block and has a posted speed limit of 30 miles per hour. Additionally, public transportation has a strong presence in the area with 15 Metro Transit stops in the segment.

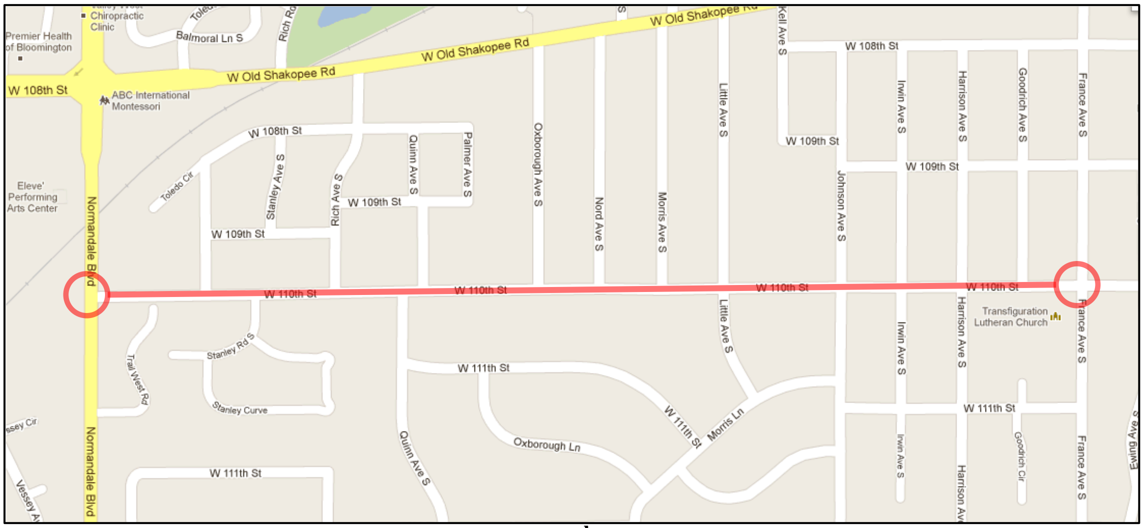

Figure 4.7: West 110th Street Study Area

Source: Google Maps. http://www.google.com/maps (Accessed 12 July, 2012).

<u>4.2.3.1 Conditions Before and After Reconstruction</u>

In 2009, the portion of W. 110th Street was chip sealed as part of the city's Pavement Management Plan (PMP) and consequentially chosen as a candidate for City of Bloomington Collector Street Reconfiguration Program. The program objective is to "evaluate collector street striping configuration considering goals outlined in the City Comprehensive Plan" such as reducing congestion, providing safe and extensive pedestrian and bicycle accommodations, and improving living conditions in the community.

Before reconstruction, the cross-section was composed of four lanes, 10 to 11 feet wide. Parking was allowed in the two outermost lanes during off-peak hours. After reconstruction, two 12 foot through lanes and two dedicated 8 to 10 foot parking lanes were provided. A cross-section showing one of two current parking configurations (10 feet parking lanes) is presented in Figure 4.8. Pre-existing sidewalks on both sides of the street were not modified during reconstruction. Figures 4.9, 4.10, and 4.11 present a comparison between before and after conditions for a section of the study area in proximity of France Avenue intersection as an example. Figure 4.9 and Figure 4.10 illustrate the conditions before construction showing a four lane undivided roadway. Figure 4.11 shows conditions after construction with a two-lane roadway and parking lanes clearly delineated. There were no bicycle lanes constructed in this section.

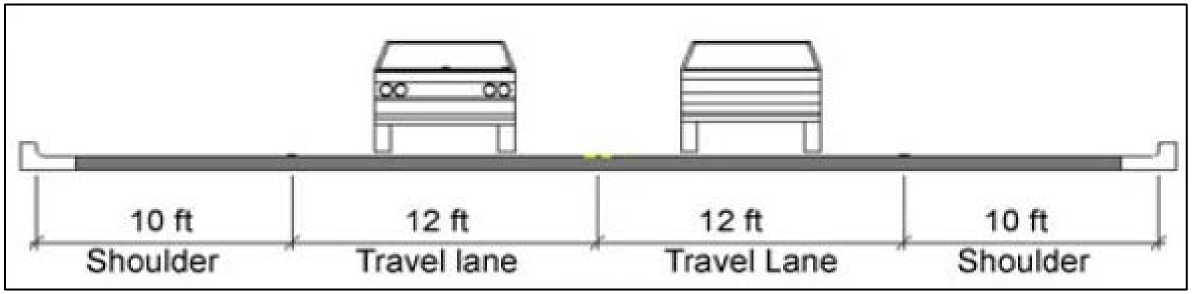

Figure 4.8: West 110th Street Cross-Section Featuring 10 Feet Parking Lanes
Source: City of Bloomington, Minnesota Public Works: Administration, Engineering, Maintenance, and Utilities.

Figure 4.9: Example of West 110th Street Section (Near France Avenue) Before Reconstruction
Source: Google Earth 6.2.2.6613. (March, 2006). Lyndale Avenue 93°19'50.75"W, 44°48'17.34"N, Elevation 1718 ft. http://www.google.com/earth/index.html (Accessed 12 July, 2012).

Figure 4.10: Example of West 110th Street Section (Near France Avenue) Before Reconstruction Showing Four-Lane Roadway and Off-Peak Parking in Outside Lanes

Source: Google Earth 6.2.2.6613. (March, 2006). Lyndale Avenue, 93°19'50.75"W, 44°48'17.34"N, Elevation 1718 ft. http://www.google.com/earth/index.html (Accessed 12 July, 2012).

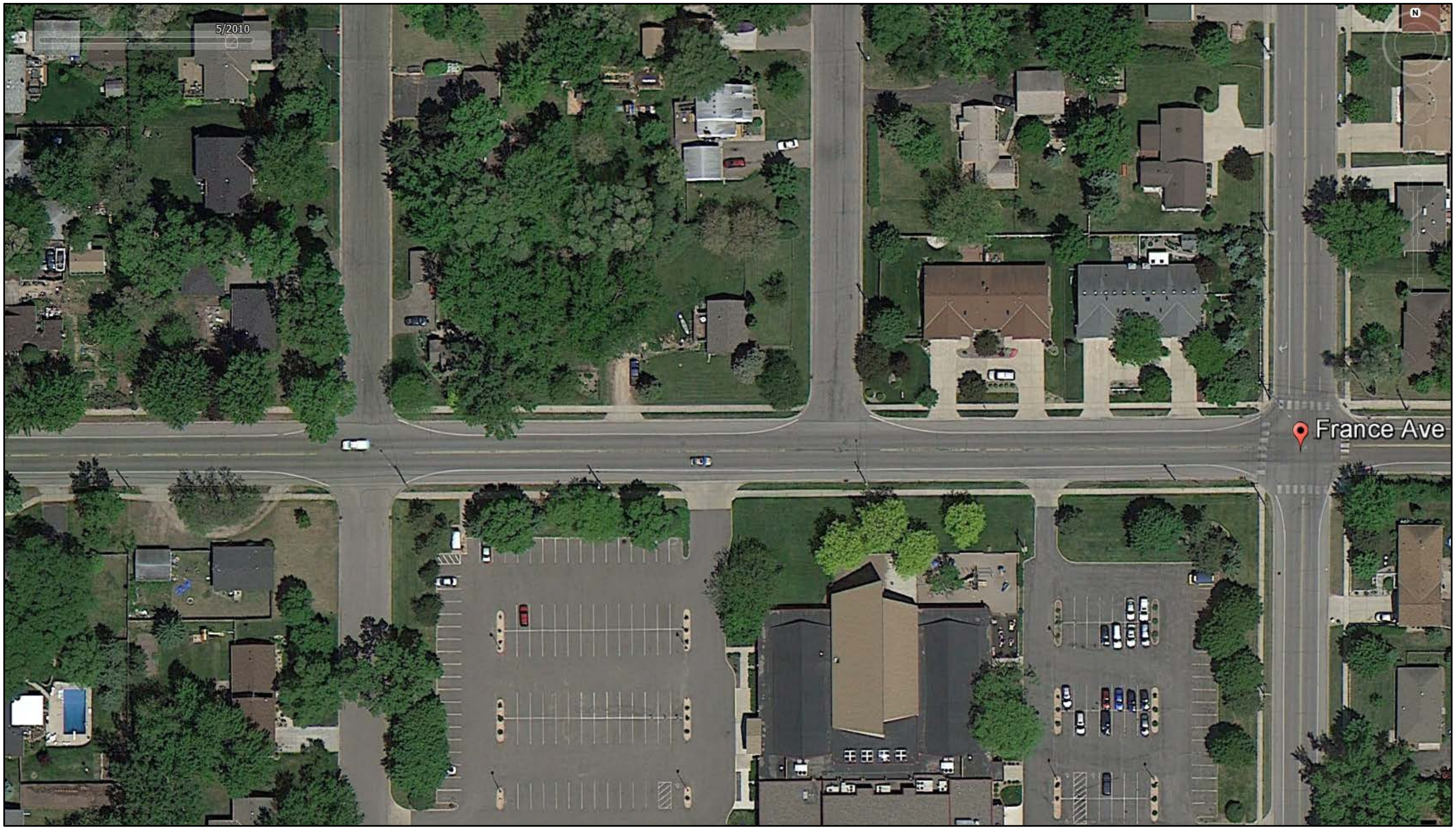

Figure 4.11: Example of West 110th Street Section (Near France Avenue) After Reconstruction Showing Two-Lane Roadway and Delineated Parking Lanes

Source: Google Earth 6.2.2.6613. (March, 2006). Lyndale Avenue, 93°19'50.75"W, 44°48'17.34"N, Elevation 1718 ft. http://www.google.com/earth/index.html (Accessed 12 July, 2012).

4.2.3.2 Crash Data Analysis

Safety evaluation of reconstruction work at West 110th Street was conducted using 2 years of before and after crash data, respectively. Table 4.5 presents data on AADT and total number of crashes at the site in periods prior to and after the reconstruction. No detailed crash data analysis could be conducted because of the small number of crashes at this location as evident in Table 4.5. Furthermore, the HSM method for EB analysis only applies to arterial roads. Therefore, it is difficult to assess the safety effects of reconstruction work at this site. Nevertheless, the crash data show that lane reduction at this location did not result in any reduction in safety performance of the road which is an important considering with respect to "road diet" projects.

Table 4.5: Crash Data for West 110th Street Study Area

W. 110th St. (Normandale Blvd. to France Ave.)		
	Before 2006 (Crashes 2007-2008)	After 2010 (Crashes 2010 - 2011)
	2 years	2 years
Segment Length	1.0 mile	
ADT	5600 – 6200	3800 - 4350
Speed Limit	30 MPH	30 MPH
Total Crashes	2	2
FI	0	0
PDO	2	2
Rear-end	1	1
Head-on	0	0
Angle	1	1
Sideswipe, same direction	0	0
Sideswipe, opposite direction	0	0
Driveway-related	0	0
Other multiple-vehicle	0	0
Collision with animal	0	0
Collision with fixed object	0	0
Collision with other object	0	0
Other single-vehicle	0	0
Bicycle Crashes	0	0
Pedestrian Crashes	0	0

4.2.4 Lake Street (5th Ave. S. to 22nd Ave. S.), Minneapolis, MN (Hennepin County)

The segment of roadway on East Lake Street between 5th Avenue South and 22nd Avenue South is 1.48 miles long (see Figure 4.12) which was reconstructed in 2006. This segment of roadway is a minor arterial. Although primarily surrounded by commercial property, the surrounding area nearby is mainly residential. Metro Transit has 10 bus stops within the study area and the posted speed limit along the segment is 30 miles per hour.

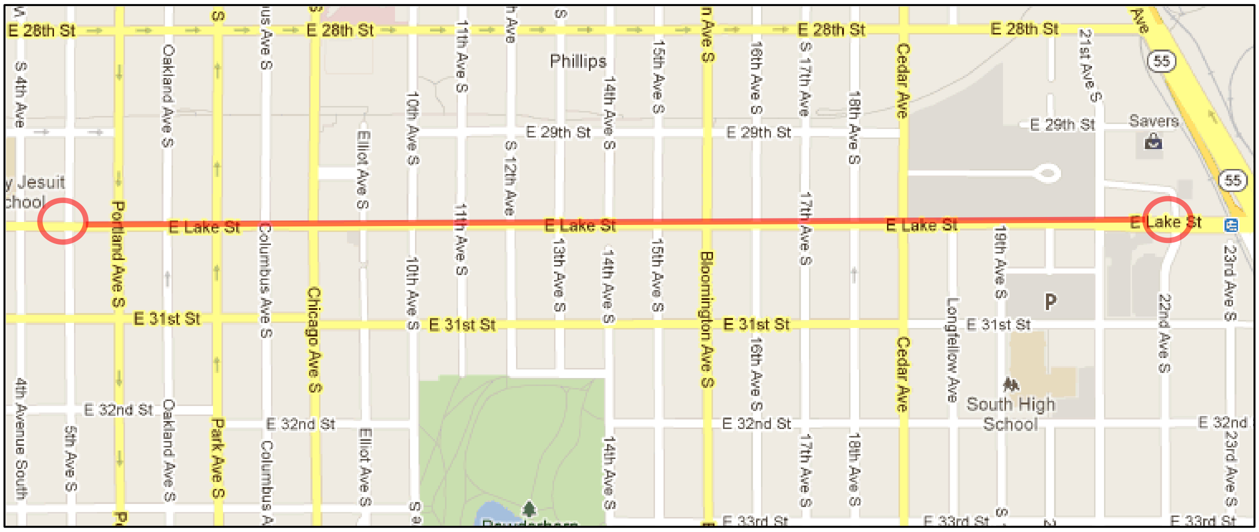

Figure 4.12: Lake Street Study Area

Source: Google Maps. http://www.google.com/maps (Accessed 12 July, 2012).

4.2.4.1 Conditions Before and After Reconstruction

Before reconstruction, East Lake Street was a four-lane undivided highway with additional parking lanes on both sides. In addition to repaving the street in 2006, the cross-section was reconfigured to include curb extensions, parking, and turning lanes. Two through lanes, varying in width from approximately 11 feet to 12.3 feet were provided in each direction. At select intersections, exclusive left-turn lanes approximately 11 feet in width were added. Parking lanes, when present, are found in one of two configurations: on one side of the road only or on both sides of the road. In all cases, parking lanes are 8 feet wide. Pedestrian accommodations remain similar to before reconstruction and consist of a sidewalk on both sides of the road that varies in width from 7 feet to approximately 21 feet (measurements including the width of the terrace).

Additional segments of Lake Street were reconstructed to the east and west of the study area segment with similar parking lanes, exclusive turn lanes, varying sidewalk widths, and curb extensions. The west segment (0.82 mile in length) was constructed between 2008 and 2009 and the east segment (1.71 miles in length) was constructed between 2006 and 2008.

Figure 4.13 shows the conditions before reconstruction while Figures 4.14 and 4.15 show the conditions after reconstruction for a section of the study area between 17th avenue and Cedar Avenue on East Lake Street to illustrate the changes in terms of curb extensions and parking lanes. No bicycle lanes were constructed at this location.

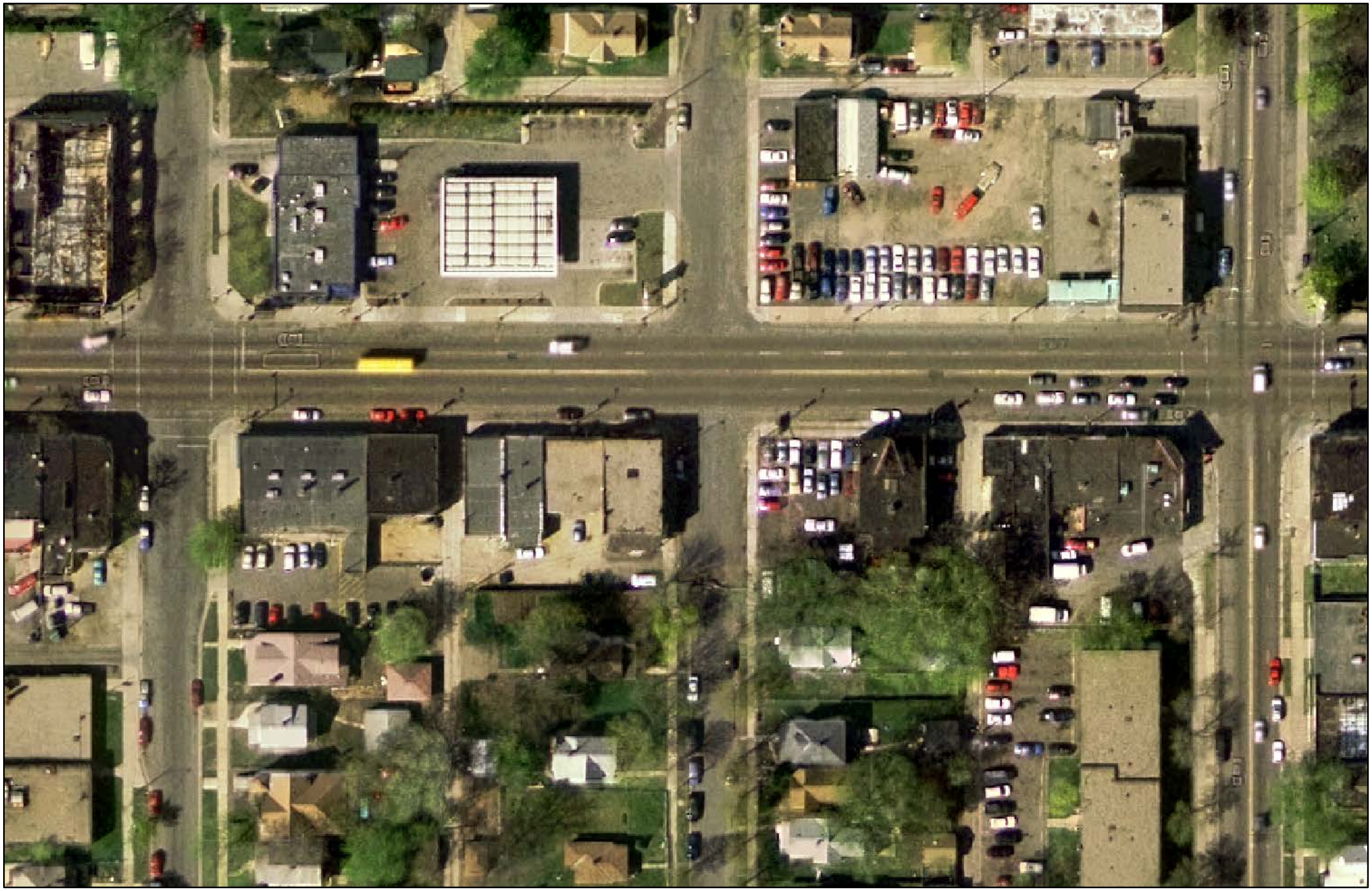

Figure 4.13: Example of East Lake Street Section (Between 17th and Cedar Avenues) Before Reconstruction
Source: USGS High Resolution Orthoimagery. (24 April, 2004). East Lake street 93°14'55.114"W, 44°56'52.159"N, Elevation 1537 ft. http://earthexplorer.usgs.gov/ (Accessed 12 July, 2012).

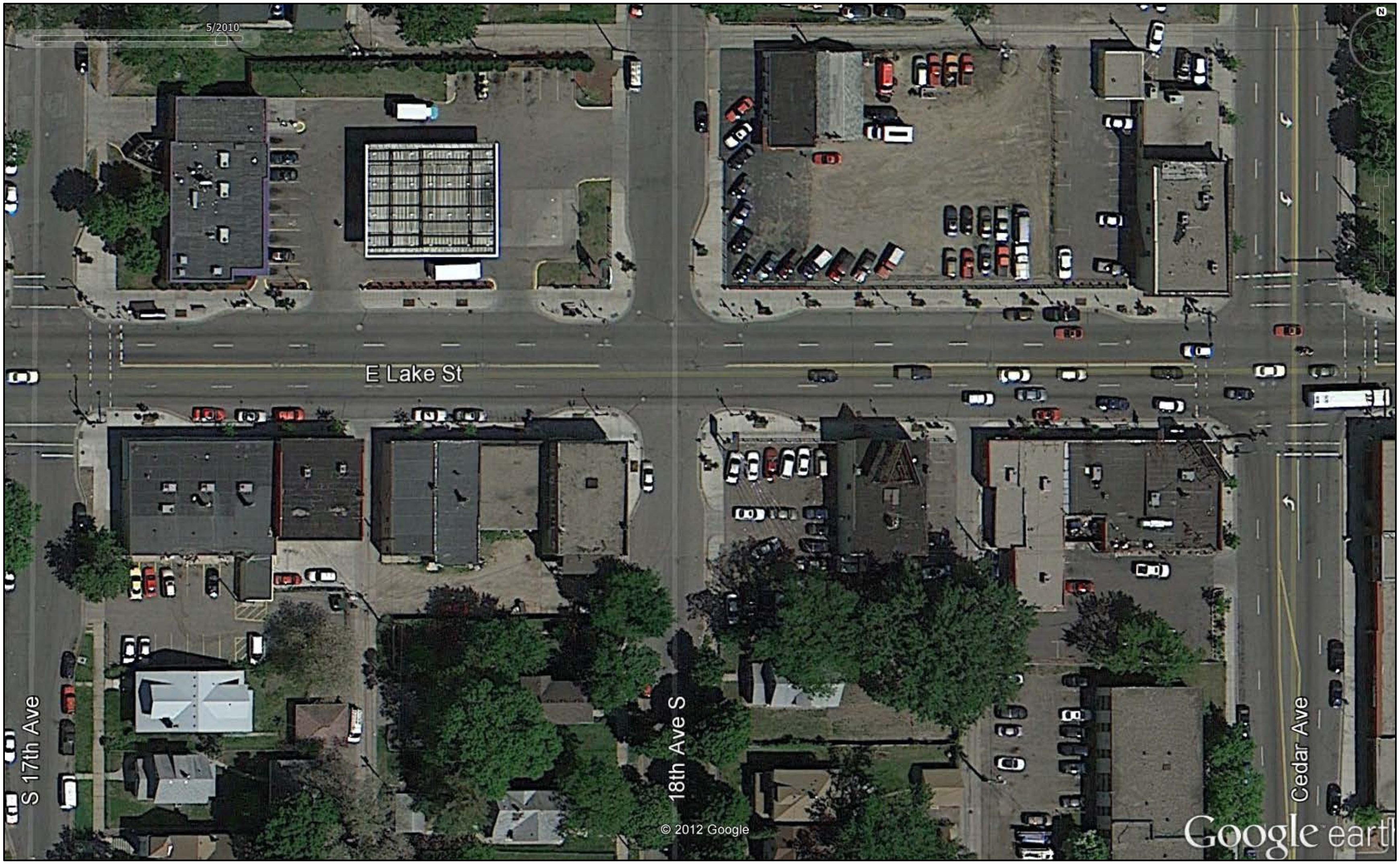

Figure 4.14: Example of East Lake Street Section (Between 17th and Cedar Avenues) After Reconstruction Showing Curb Extensions and Parking Lanes

Source: Google Earth 6.2.2.6613. (May, 2010). East Lake street 93°14'55.114"W, 44°56'52.159"N , Elevation 1537 ft. http://www.google.com/earth/index.html (Accessed 12 July, 2012).

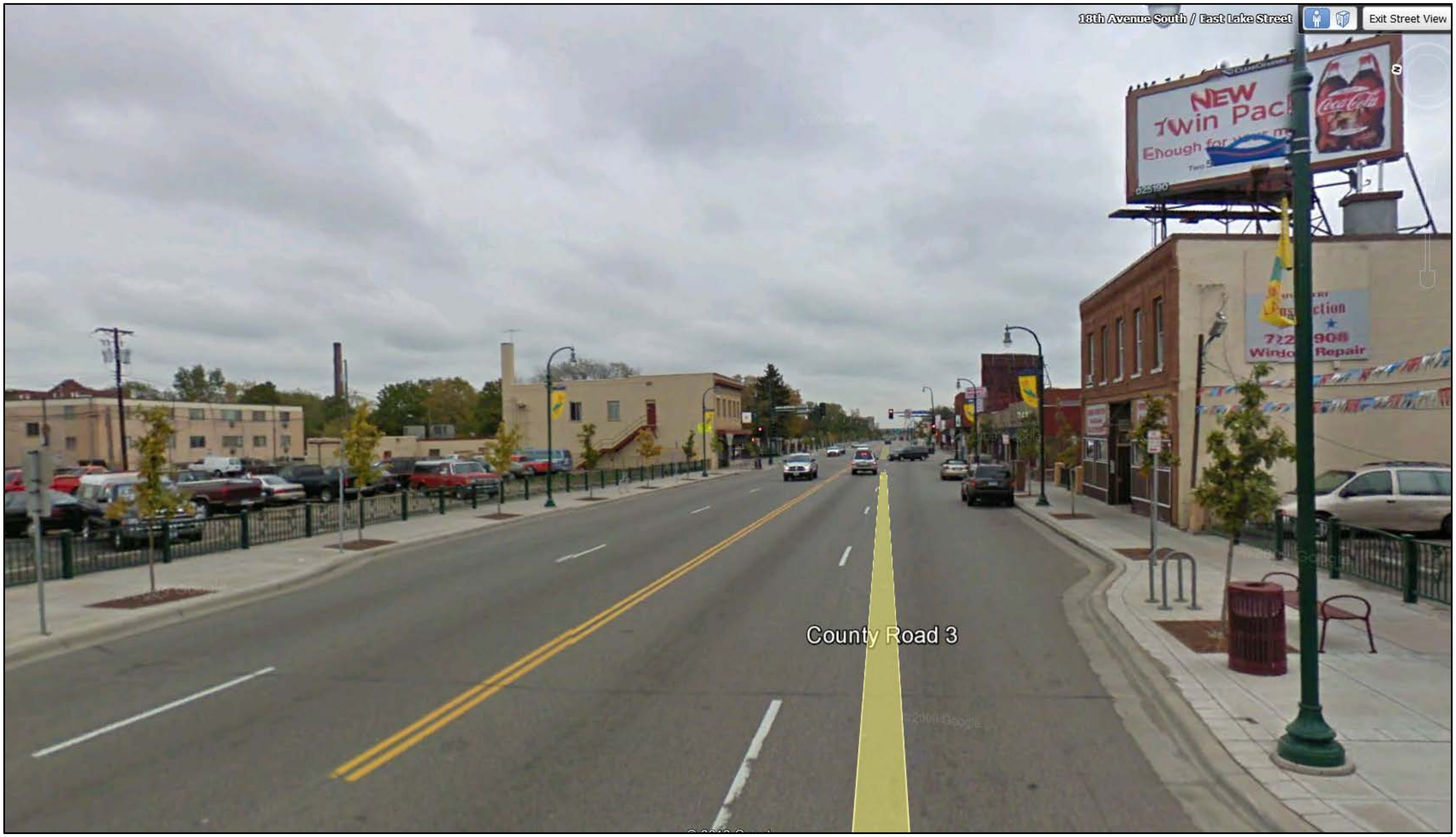

Figure 4.15: East Lake Street Cross-Section near 17th Avenue After Reconstruction Showing Curb Extensions and Parking Lanes

Source: Google Earth 6.2.2.6613. (May, 2010). East Lake street 93°14'55.114"W, 44°56'52.159"N , Elevation 1537 ft. http://www.google.com/earth/index.html (Accessed 12 July, 2012).

4.2.4.2 Crash Data Analysis

Safety evaluation of reconstruction work at Lake Street was conducted using 3.4 and 5.3 years of before and after crash data, respectively. Table 4.6 presents data on AADT and total number of crashes at the site in periods prior to and after the reconstruction. Detailed before-after crash analysis results using simple and EB methods is presented in Table 4.7.

Table 4.6: Crash Data for Lake Street Study Area

Lake Street (5th Ave S to 22nd Ave S)		
	Before (Crashes 2002-May 2005)	After (Crashes 2007 - 2012)
	3.4 years	5.3 years
Segment Length	1.48 miles	
ADT	11,100 – 16,000	18,700 – 21,500
Speed Limit	30 MPH	30 MPH
Total Crashes	486	627
FI	144	166
PDO	342	461
Rear-end	119	191
Head-on	13	17
Angle	125	175
Sideswipe, same direction	54	92
Sideswipe, opposite direction	10	18
Driveway-related	11	4
Other multiple-vehicle	124	77
Collision with animal	0	0
Collision with fixed object	21	32
Collision with other object	9	19
Other single-vehicle	0	2
Bicycle Crashes	8	37
Pedestrian Crashes	15	40

It is important to note that traffic volumes increased significantly, by up to 50 percent, after reconstruction, likely contributing to the increases in crash frequency identified. Results from both the simple before-after and EB analyses of crash types show a decrease in the number of head-on, angle, and driveway-related crashes. However, both the simple before-after and EB results show an increase in sideswipe and rear-end crashes. There is also an increase in single vehicles crashes after reconstruction. The results of both simple before-after and EB analysis of crash severity show a decrease in severity of crashes. Although the results show some increases in certain types of crashes, the overall number of crashes have reduced suggesting that the changes at this site did not result in any major safety deterioration, especially the severity of crashes.

The result of simple before-after analysis of bicycle and pedestrian crashes shows an increase in the number of bicycle and pedestrian crashes possibly due to an increase in bicycle, pedestrian, and overall traffic in the after period. In the absence of bicycle and pedestrian counts, it is difficult to identify impacts conclusively.

Table 4.7: Summary Results of Simple and EB Before-After Crash Analysis - Lake Street

Before-After Analysis by Crash Type

	Simple Before-After Analysis			Empirical Bayes Analysis		
Crash Type	Observed Crashes - Before Period (per year)	Observed Crashes - After Period with Treatment (per year)	Percent Change (%)	Expected Average Crashes - After Period W/O Treatment (Per Year)	Crashes Reduced (or increased) in After Period (Expected - Observed)	Percent Change using Expected Average Crashes - After Period W/O Treatment Compared with Observed Crashes - After Period with Treatment (%)
When interpreting the results, caution should be used when crashes per year are less than 0.5 or less than 2 year of crash data is available						
Multiple Vehicles						
Rear End	34.9	35.8	**2.8**	34.4	-1.4	**4.0**
Head On	3.8	3.2	**-16.3**	2.0	-1.2	**59.4**
Angle	36.6	32.8	**-10.4**	36.4	3.6	**-9.9**
Sideswipe - Same Direction	15.8	17.3	**9.1**	13.5	-3.8	**28.2**
Sideswipe Opposite Direction	2.9	3.4	**15.3**	1.4	-2.0	**149.3**
Other Multiple Vehicle	36.3	14.4	**-60.2**	36.0	21.6	**-59.9**
Driveway Related	3.2	0.8	**-76.7**	4.6	3.9	**-83.8**
Single Vehicle						
Animal Crash	0.0	0.0	**0.0**	0.0	0.0	**0.0**
Fixed Object Crash	6.2	6.0	**-2.4**	6.0	0.0	**0.1**
Other Object Crash	2.6	3.6	**35.2**	2.4	-1.2	**50.5**
Other Single Vehicle Crash	0.0	0.4	**100.0**	0.0	-0.4	**100.0**
Total	142.4	117.6	**-17.4**	136.7	19.1	**-14.0**

Before-After Analysis by Crash Severity

	Simple Before-After Analysis			Empirical Bayes Analysis		
Crash Severity	Observed Crashes - Before Period (per year)	Observed Crashes - After Period with Treatment (per year)	Percent Change (%)	Expected Average Crashes - After Period W/O Treatment (Per Year)	Crashes Reduced (or increased) in After Period (Expected - Observed)	Percent Change using Expected Average Crashes - After Period W/O Treatment Compared with Observed Crashes - After Period with Treatment (%)
FI	42.2	31.1	**-26.2**	42.2	11.0	**-26.1**
PDO	100.2	86.5	**-13.7**	94.6	8.1	**-8.6**
Total	142.4	117.6	**-17.4**	136.7	19.1	**-14.0**

Simple Before-After Analysis - Bike and Pedestrian Crashes Only

Crash Type	Observed Crashes - Before Period (per year)	Observed Crashes - After Period with Treatment (per year)	Percent Change (%)
Bike Crashes	2.34	6.94	**196.1**
Pedestrian Crashes	4.39	7.50	**70.7**
Grand Total	6.74	14.44	**114.4**

4.2.5 76th Street (Xerxes Ave. S. to 22nd Ave. S.), Richfield, MN

The section of West 76th Street between Xerxes Avenue South and South 12th Avenue (see Figure 4.16) is 1.9 miles in length, classified as an arterial, and has a speed limit of 30 miles per hour. The area is predominantly residential and has significant transit presence with 14 bus stops along the segment, the majority of which are concentrated to the west of the intersection with West 77th Street.

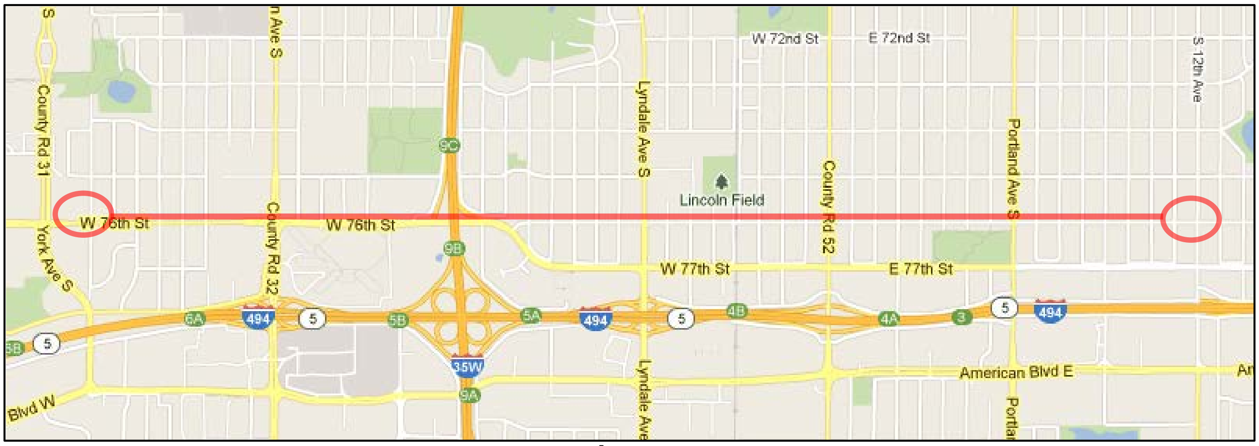

Figure 4.16: 76th Street Study Area

Source: Google Maps. http://www.google.com/maps (Accessed 12 July, 2012).

4.2.5.1 Conditions Before and After Reconstruction

Construction was completed in fall of 2011 and involved converting the old configuration of two lanes in each direction of travel to a new design in which one 11 foot travel lane and one 5 foot bicycle lane served each direction of travel. To further meet the needs of bicyclists and pedestrians, an 8 feet multi-use path was constructed on the north side of 76th Street and 5.5 to 6 foot sidewalk was built on the street's south side. The reasoning behind the provision of a multi-use path in addition to the bicycle lanes on the roadway was to cater for cyclists of varying degrees of skill and comfort level; that is, on-street lanes are more likely to be used by more-experienced riders who feel more comfortable riding closer to traffic and want to avoid the many residential driveways in the area. As a result of the current configuration, parking is no longer allowed on the street.

Figure 4.17 highlights the changes in right-of-way allocation along 76th Street both prior to and following reconstruction. Figures 4.18 and 4.19 illustrate the comparison between the conditions before and after reconstruction for a subsection of the study area between Garfield and Grand Avenue. Figure 4.17 clearly shows a four-lane roadway without bicycle lanes whereas Figure 4.18 shows conversion to two-lane roadway along with a bicycle lane and multi-use path south of 76th street. Figures 4.20 and 4.21 present an example of cross-section comparison before and after resconstruction.

Figure 4.17: Right-of-Way Allocation for 76th Street between Xerxes and Lyndale Avenues Before and After Reconstruction

Source: City of Richfield, Minnesota, Howard R. Green Company.

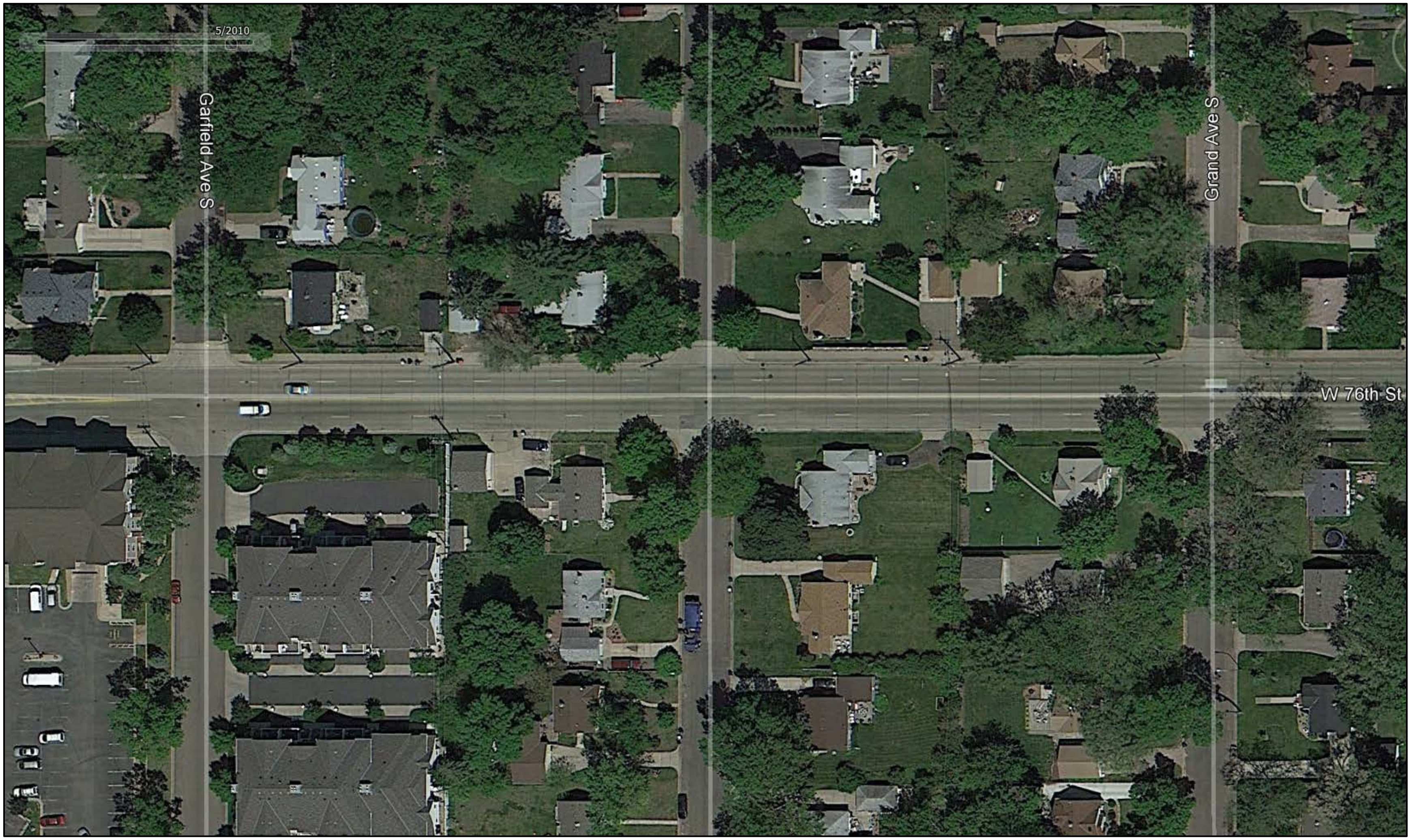

Figure 4.18: Example of 76th Street Section (Between Garfield and Grand Avenues) Before Reconstruction Showing Four-Lane Roadway

Source: Google Earth 6.2.2.6613. (May, 2010). 76th street 93° 17' 9.0744"W, 44° 51' 55.8432"N, Elevation 1673 ft. http://www.google.com/earth/index.html (Accessed 12 July, 2012).

Figure 4.19: Example of 76th Street Section (Between Garfield and Grand Avenues) After Reconstruction Showing Two-Lane Roadway with In-Road Bicycle Lanes and Multi-Use Path

Source: Google Earth 6.2.2.6613. (April, 2012). 76th street 93° 17' 9.0744"W, 44° 51' 55.8432"N, Elevation 1673 ft. http://www.google.com/earth/index.html (Accessed 12 July, 2012).

Figure 4.20: Example of 76th Street Cross-Section Before Reconstruction
Source: City of Richfield, Minnesota

Figure 4.21: Example of 76th Street Cross-Section After Reconstruction
Source: City of Richfield, Minnesota

4.2.5.2 Crash Data Analysis

Safety evaluation of reconstruction work at 76th Street was conducted using 1.0 and 0.7 years of before and after crash data, respectively. Table 4.8 presents data on AADT and total number of crashes at the site in periods prior to and after the reconstruction. Detailed before-after crash analysis results using simple and EB methods is presented in Table 4.9.

Table 4.8: Crash Data for 76th Street Study Area

76th Street (77th Street to 12th Avenue)		
	Before 2010 (Crashes 2010)	After 2011 (Crashes 2012 through 10-31-12)
	1 year	0.7 years
Segment Length	1.9 Miles	
ADT	3050 – 5300	3050 - 5300
Speed Limit	30 MPH	30 MPH
Total Crashes	14	9
FI	6	6
PDO	8	3
Rear-end	2	2
Head-on	0	0
Angle	9	6
Sideswipe, same direction	1	0
Sideswipe, opposite direction	0	0
Driveway-related	0	0
Other multiple-vehicle	0	0
Collision with animal	0	0
Collision with fixed object	2	1
Collision with other object	0	0
Other single-vehicle	0	0
Bicycle Crashes	0	0
Pedestrian Crashes	0	0

The results of simple before-after analysis of crash types show a slight increase in rear-end crashes. The results of EB analysis shows an increase in both rear-end and angle crashes. However, the results are inconclusive because the number of years of available crash data was not ideal; therefore caution should be used in interpreting the results. Overall, the changes made at this site do not show any adverse safety impacts in terms of frequency or severity.

The analysis of bicycle and pedestrian crashes could not be completed because there were no reported bicycle and pedestrian crashes for the limited before and after periods at this site. Overall, since the crash data available for this location was less than 2 years in the before and after periods, the results of simple before-after and EB analysis are considered inconclusive.

Table 4.9: Summary Results of Simple and EB Before-After Crash Analysis Results - 76th Street

Before-After Analysis by Crash Type						
	Simple Before-After Analysis			Empirical Bayes Analysis		
Crash Type	Observed Crashes - Before Period (per year)	Observed Crashes - After Period with Treatment (per year)	Percent Change (%)	Expected Average Crashes - After Period W/O Treatment (Per Year)	Crashes Reduced (or increased) in After Period (Expected - Observed)	Percent Change using Expected Average Crashes - After Period W/O Treatment Compared with Observed Crashes - After Period with Treatment (%)
When interpreting the results, caution should be used when crashes per year are less than 0.5 or less than 2 year of crash data is available						
Multiple Vehicles						
Rear End	2.0	2.7	**33.3**	2.5	-0.2	**7.4**
Head On	0.0	0.0	**0.0**	0.1	0.1	**-100.0**
Angle	9.0	8.0	**-11.1**	3.9	-4.1	**104.3**
Sideswipe - Same Direction	1.0	0.0	**-100.0**	1.0	1.0	**-100.0**
Sideswipe Opposite Direction	0.0	0.0	**0.0**	0.2	0.2	**-100.0**
Other Multiple Vehicle	0.0	0.0	**0.0**	0.2	0.2	**-100.0**
Driveway Related	0.0	0.0	**0.0**	1.1	1.1	**-100.0**
Single Vehicle						
Animal Crash	0.0	0.0	**0.0**	0.0	0.0	**-100.0**
Fixed Object Crash	2.0	1.3	**-33.3**	2.1	0.8	**-36.8**
Other Object Crash	0.0	0.0	**0.0**	0.0	0.0	**-100.0**
Other Single Vehicle Crash	0.0	0.0	**0.0**	0.3	0.3	**-100.0**
Total	14.0	12.0	**-14.3**	11.4	-0.6	**5.5**

Before-After Analysis by Crash Severity						
	Simple Before-After Analysis			Empirical Bayes Analysis		
Crash Severity	Observed Crashes - Before Period (per year)	Observed Crashes - After Period with Treatment (per year)	Percent Change (%)	Expected Average Crashes - After Period W/O Treatment (Per Year)	Crashes Reduced (or increased) in After Period (Expected - Observed)	Percent Change using Expected Average Crashes - After Period W/O Treatment Compared with Observed Crashes - After Period with Treatment (%)
FI	6.0	8.0	**33.3**	3.9	-4.2	**107.5**
PDO	8.0	4.0	**-50.0**	7.5	3.5	**-46.8**
Total	14.0	12.0	**-14.3**	11.4	-0.6	**5.5**

Simple Before-After Analysis - Bike and Pedestrian Crashes Only			
Crash Type	Observed Crashes - Before Period (per year)	Observed Crashes - After Period with Treatment (per year)	Percent Change (%)
Bike Crashes			NA
Pedestrian Crashes			NA
Grand Total			NA

4.2.6 TH 14 (Highland Avenue) (Intersection), New Ulm, MN

As compared with other locations analyzed in this report which comprised of a segment section with multiple intersections, the study site selected in New Ulm contained only one intersection between TH 14 and North Highland Avenue as seen in Figure 4.22. This unsignalized intersection of two minor arterials with posted speed limits of 55 miles per hour, is in a rural area although it is not far from residential development to the east. A two-way stop control scheme is in place with the stop signs located on north and south approaches of Highland Avenue. There are no bus stops in the area and access points in the immediate vicinity of the intersection are few.

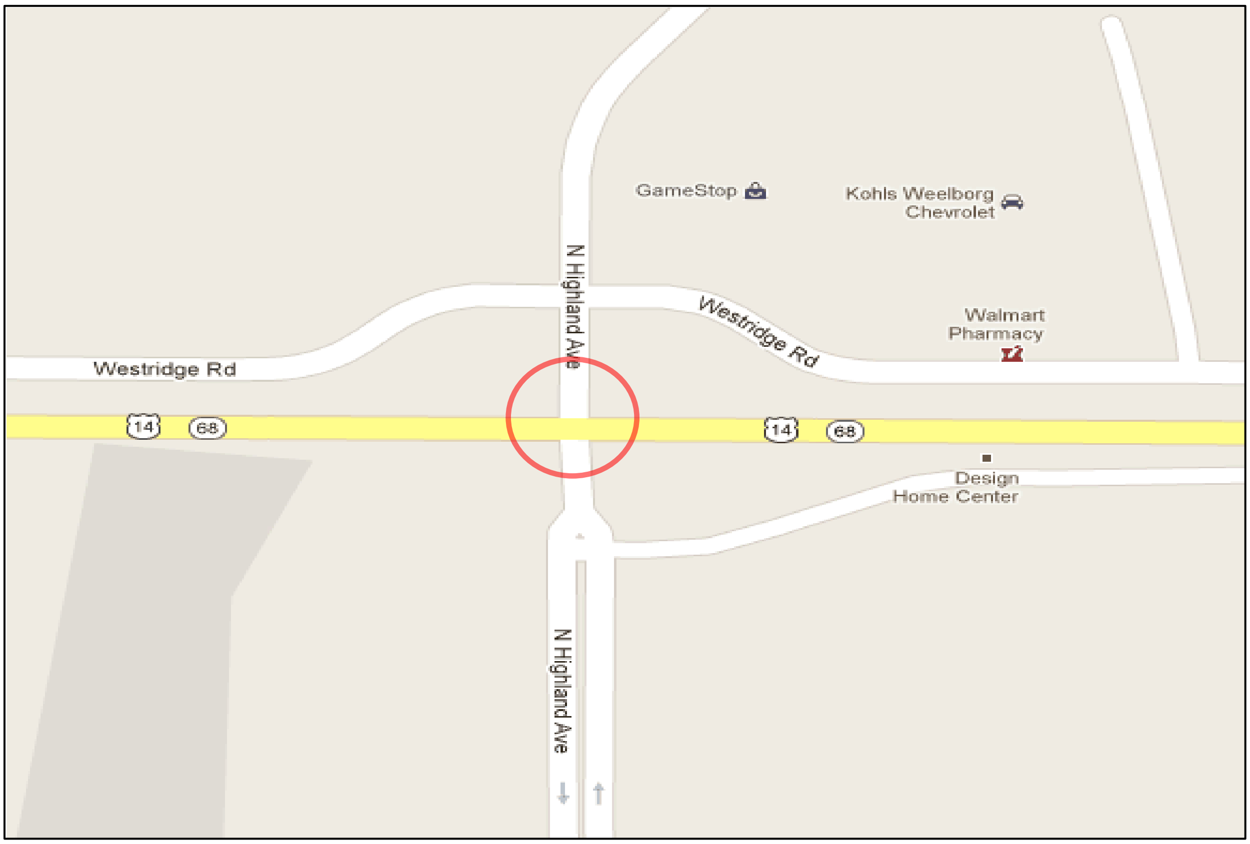

Figure 4.22: TH 14 Study Area

Source: Google Maps. http://www.google.com/maps (Accessed 12 July, 2012).

4.2.6.1 Conditions Before and After Reconstruction

In 2004, as part of a MnDOT Highway 14 Improvement Plan, the lane configuration on TH 14 was converted to a six lane cross-section at the intersection with Highland Avenue. On the eastbound leg of the intersection, in the eastbound direction, TH 14 now has two 12 foot through lanes surrounded by a 12 foot exclusive left-turn lane and a 12 foot exclusive right-turn lane; the eastbound leg also has two 12 foot through lanes and an 8 foot shoulder section in the westbound direction. The two directions of travel on TH 14 are separated by a 10 to 20 foot wide raised concrete median. Another improvement plan called for the construction of a 6 foot sidewalk and 10 foot bicycle path on Highland Avenue, just south of TH 14. A sidewalk was constructed on both sides of Highland Avenue, while the bicycle path was only added along the west side of the road.

Figures 4.23 and 4.24 illustrate the differences before and after reconstruction of the bicycle lane and sidewalks on Highland Avenue on the south leg of the intersection.

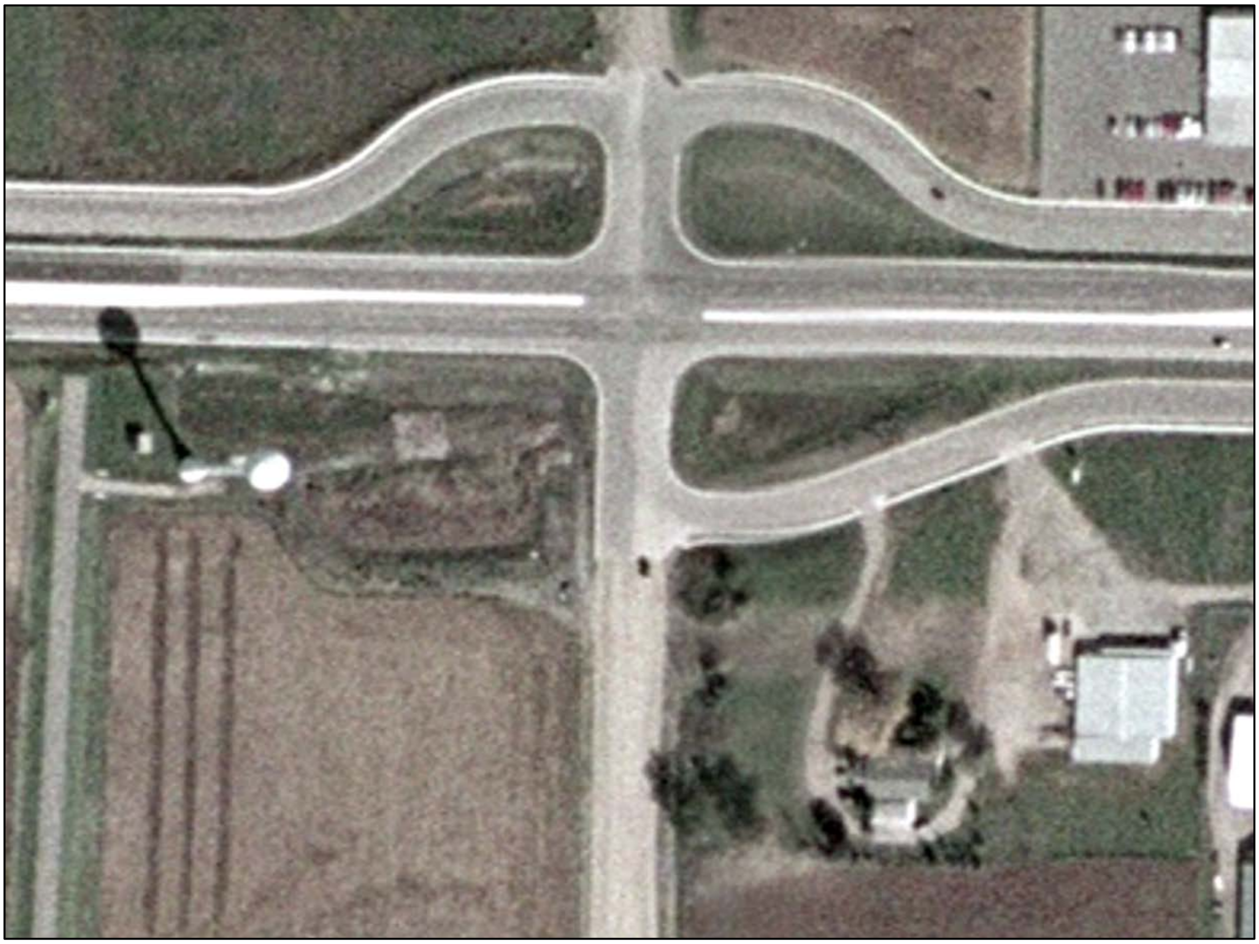

Figure 4.23: TH 14 and Highland Avenue Intersection Before Reconstruction
Source: USGS High Resolution Orthoimagery. (1 August, 2006). Highland Avenue and TH 14, 94°29'50.454"W, 44°19'34.552"N, Elevation 2292 ft. http://earthexplorer.usgs.gov/ (Accessed 12 July, 2012).

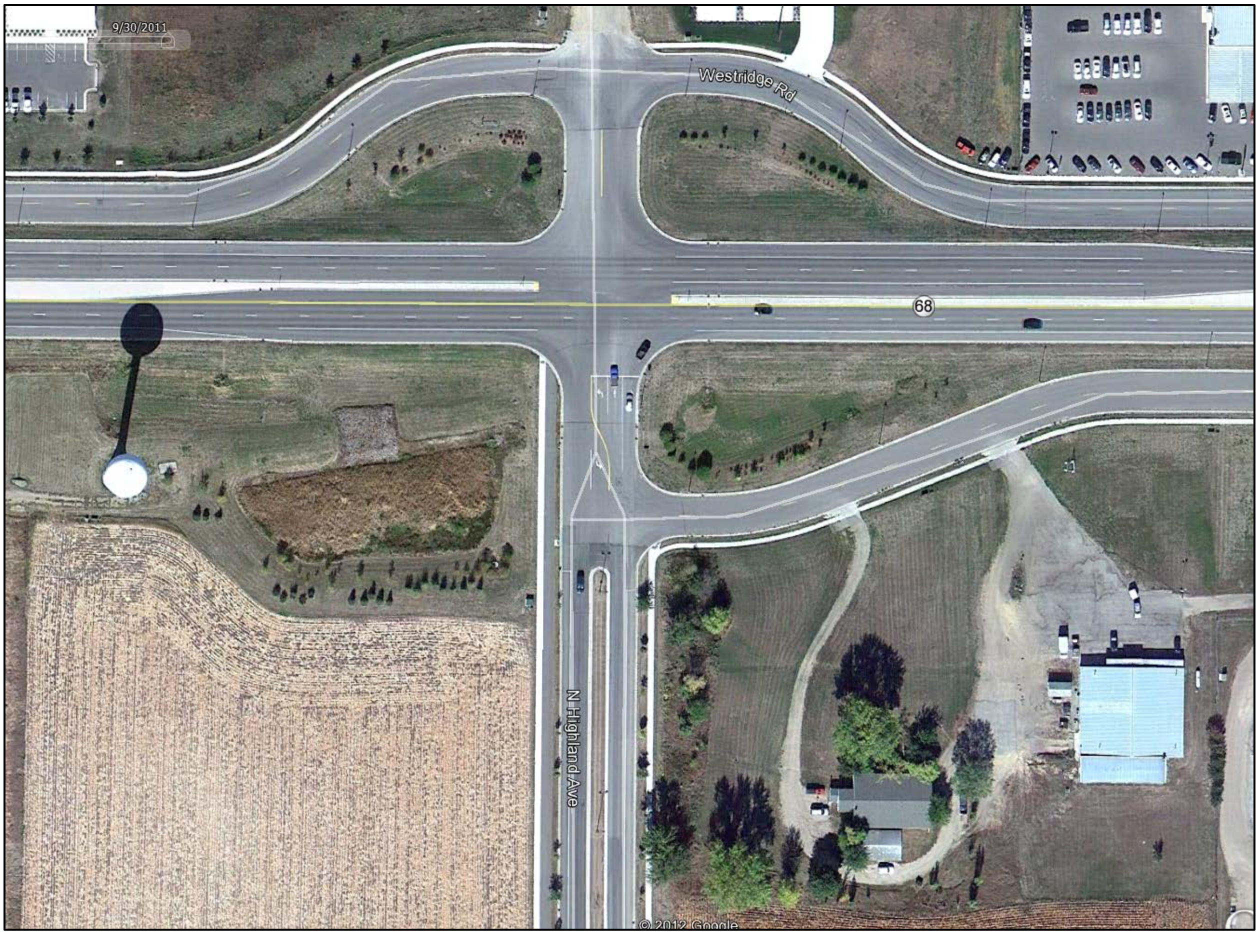

Figure 4.24: TH 14 and Highland Avenue Intersection After Reconstruction Showing Bicycle Path and Sidewalks along Highland Avenue

Source: Google Earth 6.2.2.6613. (30 September, 2011). Highland Avenue and TH 14, 94°29'50.454"W, 44°19'34.552"N, Elevation 2292 ft. http://www.google.com/earth/index.html (Accessed 12 July, 2012).

4.2.6.2 Crash Data Analysis

Safety evaluation of reconstruction work at TH 14 and Highland Avenue intersection could not be completed because there was no crash data available for the before period. Table 4.10 shows data on ADT and both the frequency and type of crashes occurring at the intersection in the after period.

Table 4.10: Crash Data for TH 14 Study Area

TH 14 & Highland Avenue		
	Before (2001) (Crashes 2001)	After (2010) (Crashes 2008 - 2012)
Segment Length	Intersection	
ADT	4350	4600
Speed Limit	55 MPH	55 MPH
Total Crashes	N/A*	10
FI		0
PDO		7
Rear-end		1
Head-on		1
Angle		4
Sideswipe, same direction		2
Sideswipe, opposite direction		1
Driveway-related		0
Other multiple-vehicle		1
Collision with animal		0
Collision with fixed object		2
Collision with other object		0
Other single-vehicle		0
Bicycle Crashes		0
Pedestrian Crashes		0

* Before period crash data was not available

4.2.7 TH 169 (TH 22 to Union St.), St. Peter, MN

The portion of TH 169 from TH 22/West Jackson Street to West Union Street spans approximately 1.6 miles in length and can be seen in Figure 4.25. This arterial segment, which has a speed limit of 35 miles per hour, travels through a predominantly residential area, though a segment of the corridor between Walnut Street and Chestnut Street is home to many small businesses. Access is relatively restricted due to the use of alleys behind most of the homes in the area. There are no bus stops within the study area.

<u>4.2.7.1 Conditions Before and After Reconstruction</u>

Prior to construction in 2009 and 2010, the entire segment was composed of two 12 foot travel lanes in each direction with median sections ranging from 4 feet up to 16 feet for the provision of a left-turn lane. Additionally, parking was previously only available between Walnut Street and Broadway Avenue where a 12 foot parking lane was provided on each side of TH 169. The conditions before reconstruction for TH 169 are illustrated in Figures 4.26 and 4.27. After reconstruction, several new cross-sections that were essentially variations of a four-lane divided highway were implemented. Between Jefferson Avenue and West Elm Street, the cross-section is composed of a 12 feet lane and a 14 feet lane in each direction, as well as a 20 foot two-way left-turn lane (TWLTL). A similar configuration exists between Elm Street and West Walnut Street except that the TWLTL is replaced by an 18 feet raised median with vegetation that is slightly offset from the inner travel lanes.

Between West Walnut Street and Broadway Avenue, each direction of travel has two 12 foot lanes as well as a 10 foot parking lane; the directions of travel are separated by an 18 foot raised median with vegetation as seen between Elm Street and Walnut Street. Although the lane configuration at intersections varies throughout the segment, with respect to lane width and shoulder width, they are all based on a configuration involving an added 12 foot exclusive left turn lane. Between Elm Street and Broadway Avenue, the additional width needed for the exclusive left turn lanes at intersections was gained by narrowing the median in these areas. For intersections between Broadway Avenue and W. Chatham Street, a variable width median was introduced to separate the exclusive left turn lanes from opposing through lanes. Pedestrians are accommodated via a 6 foot sidewalk on both sides of the street separated from the traveled way by a terrace with a minimum width of 6 feet. No bicycle lanes were constructed at this location. Elements of the cross-sections implemented during the reconstruction process discussed previously are seen in Figures 4.28 and 4.29.

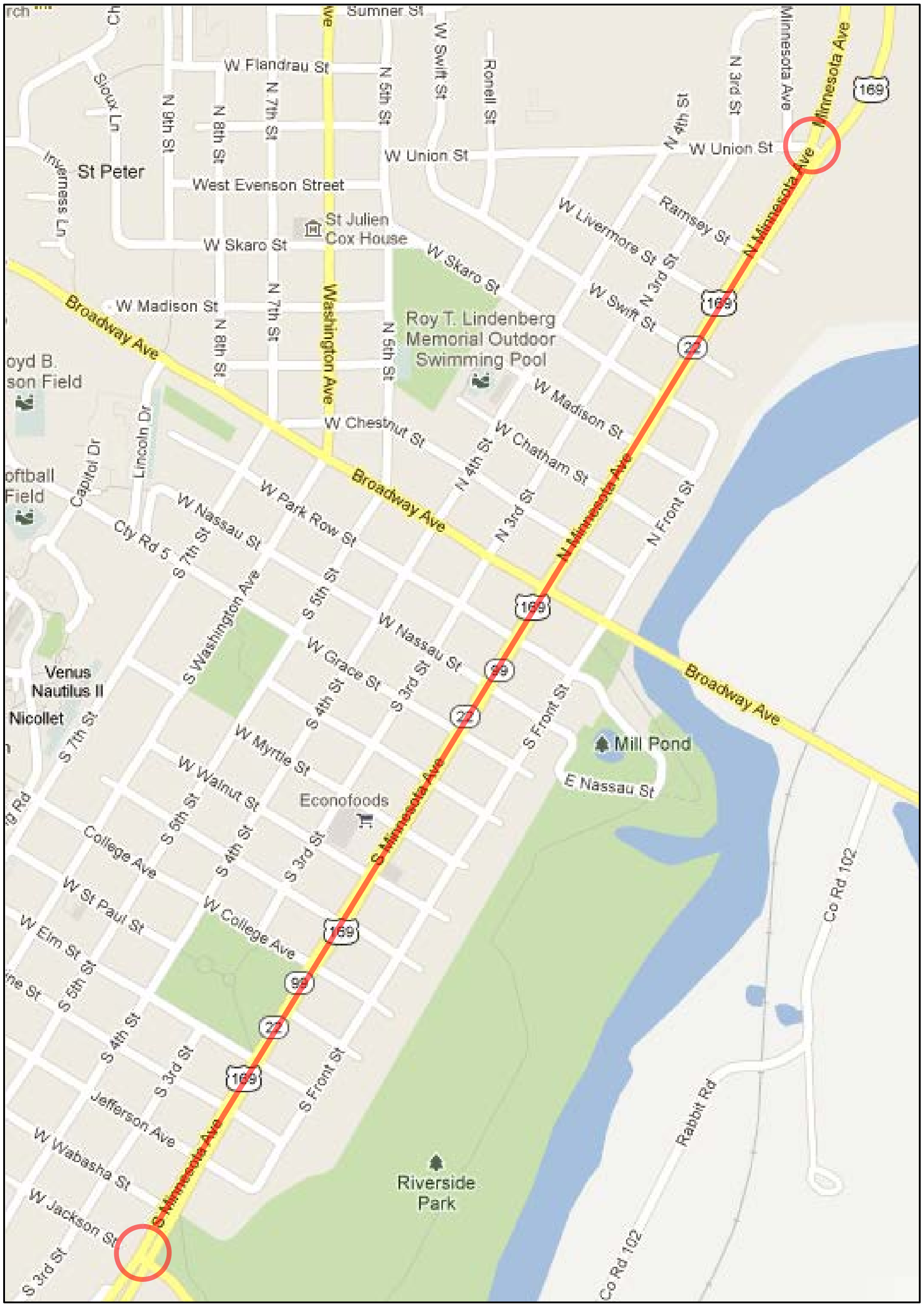

Figure 4.25: TH 169 Study Area

Source: Google Maps. http://www.google.com/maps (Accessed 12 July, 2012).

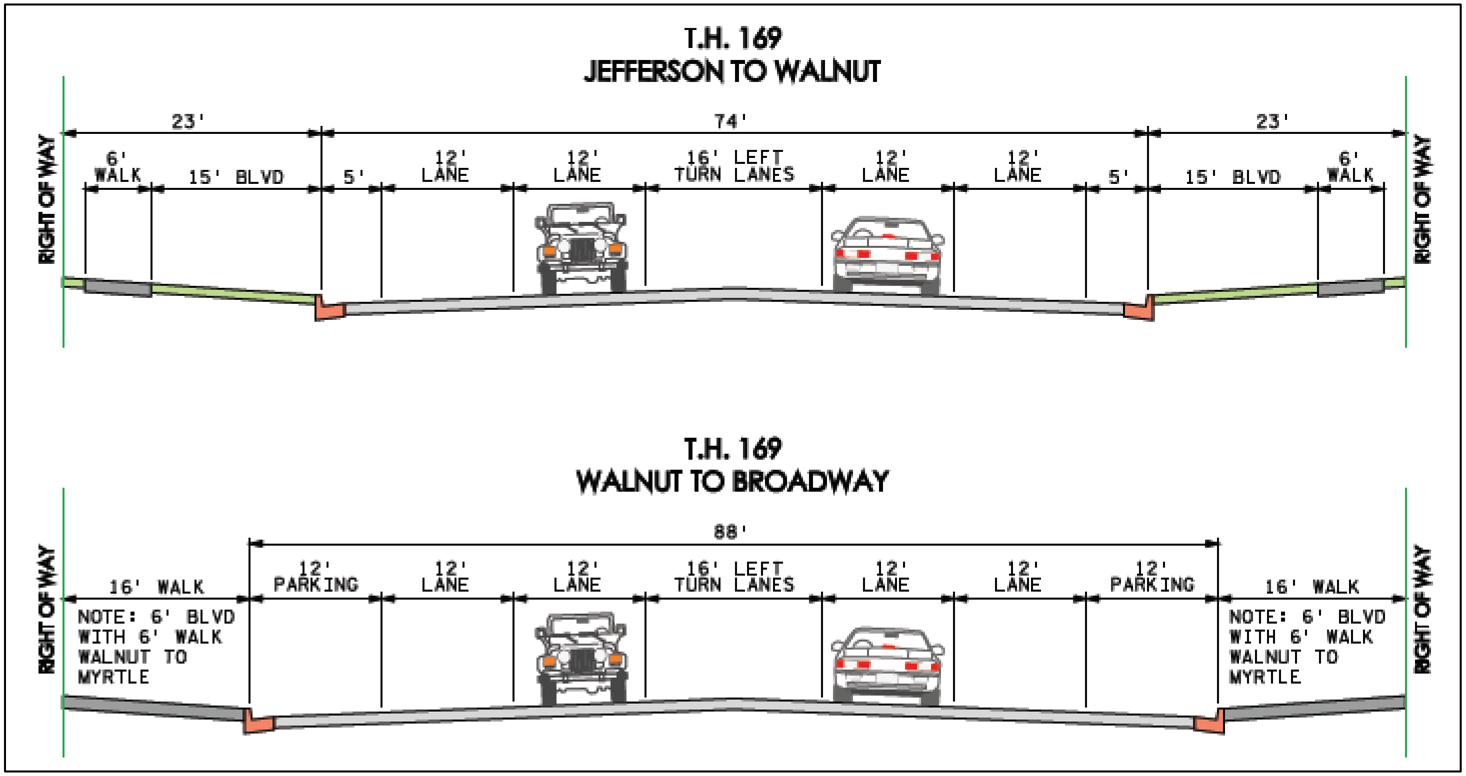

Figure 4.26: TH 169 Cross-Sections from Jefferson to Broadway Before Reconstruction
Source: Minnesota Department of Transportation

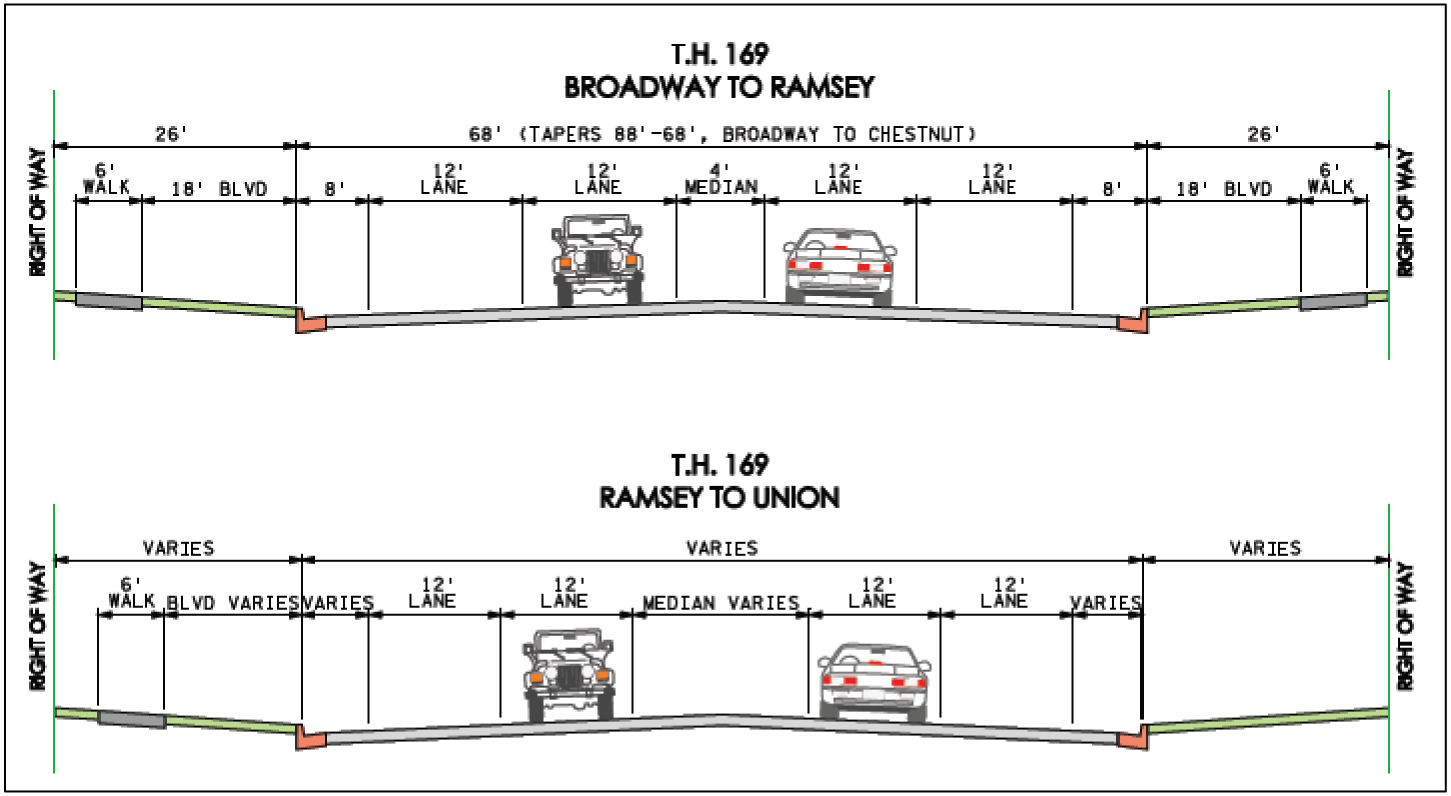

Figure 4.27: TH 169 Cross-Sections from Broadway to Union Before Reconstruction
Source: Minnesota Department of Transportation

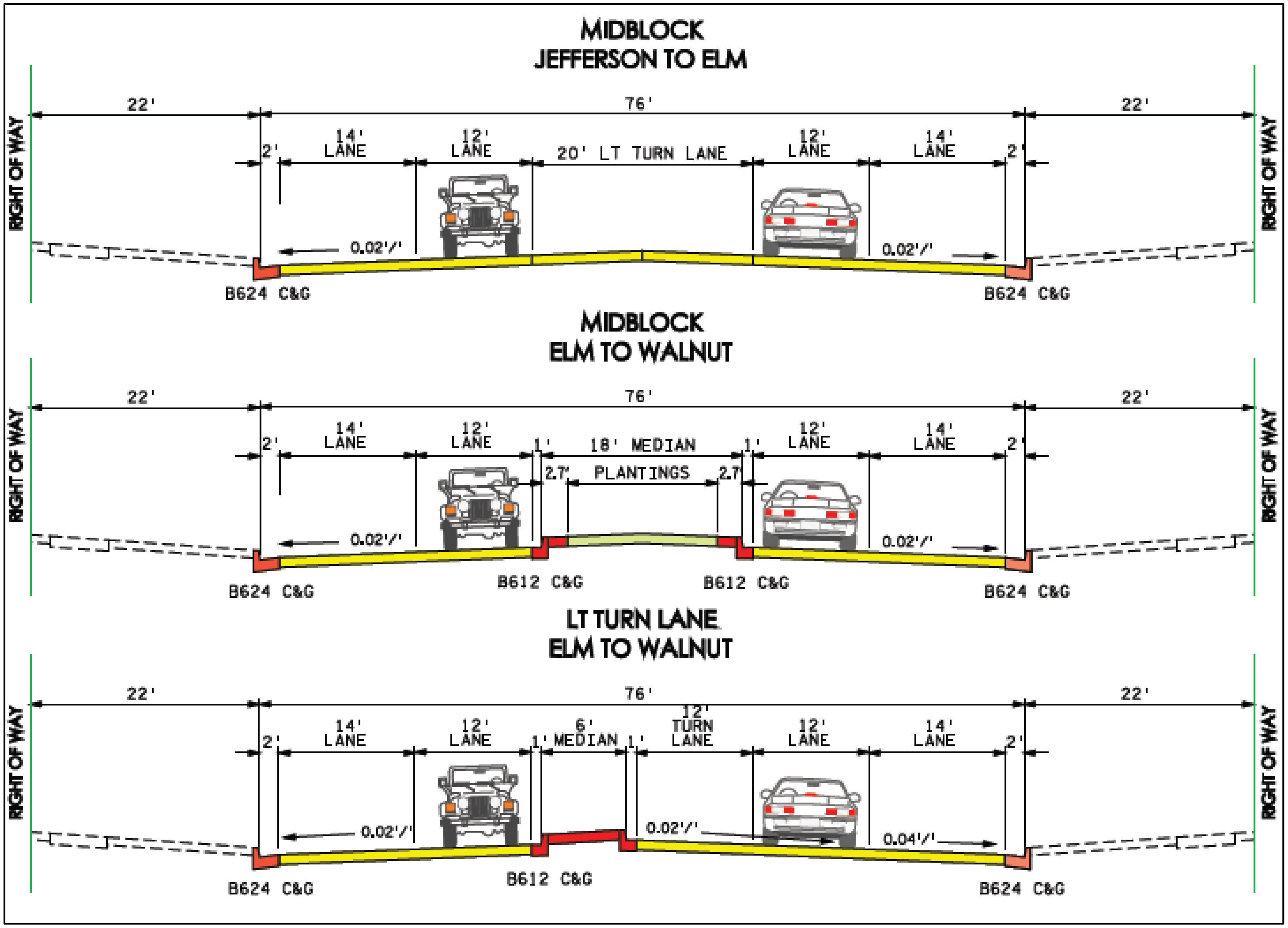

Figure 4.28: TH 169 Cross-Sections from Jefferson to Walnut After Reconstruction
Source: Minnesota Department of Transportation

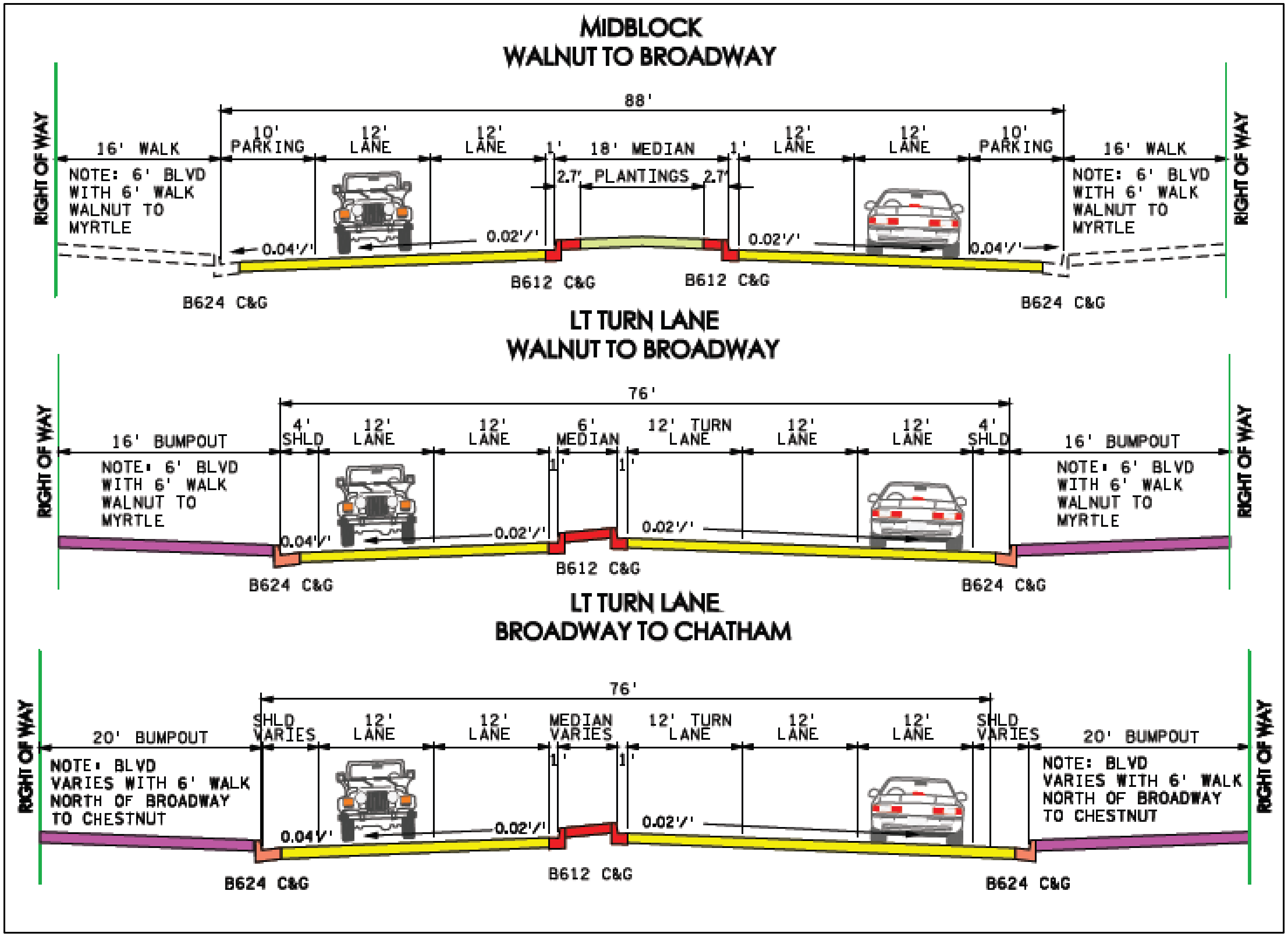

Figure 4.29: TH 169 Cross-Sections from Walnut to Chatham After Reconstruction

Source: Minnesota Department of Transportation

Figure 4.30 shows an example of the median conditions before reconstruction in the proximity of TH 169 and West Nassau Street intersection in the study area. Figure 4.31 shows an aerial view of the same intersection area with raised medians after construction. Figure 4.32 shows the two-way left-turn lane construction between West Jefferson Street and West Elm Street and Figure 4.33 shows the newly constructed raised median between West Elm Street and West Walnut Street in the study area.

Figure 4.30: Example of Median Before Reconstruction on TH 169 (Near West Nassau Street Intersection)

Source: Google Earth 6.2.2.6613. (November, 2008). TH 169 and West Nassau Street, 93°57'26.46"W, 44°19'26.43"N, Elevation 775 ft. http://www.google.com/earth/index.html (Accessed 12 July, 2012).

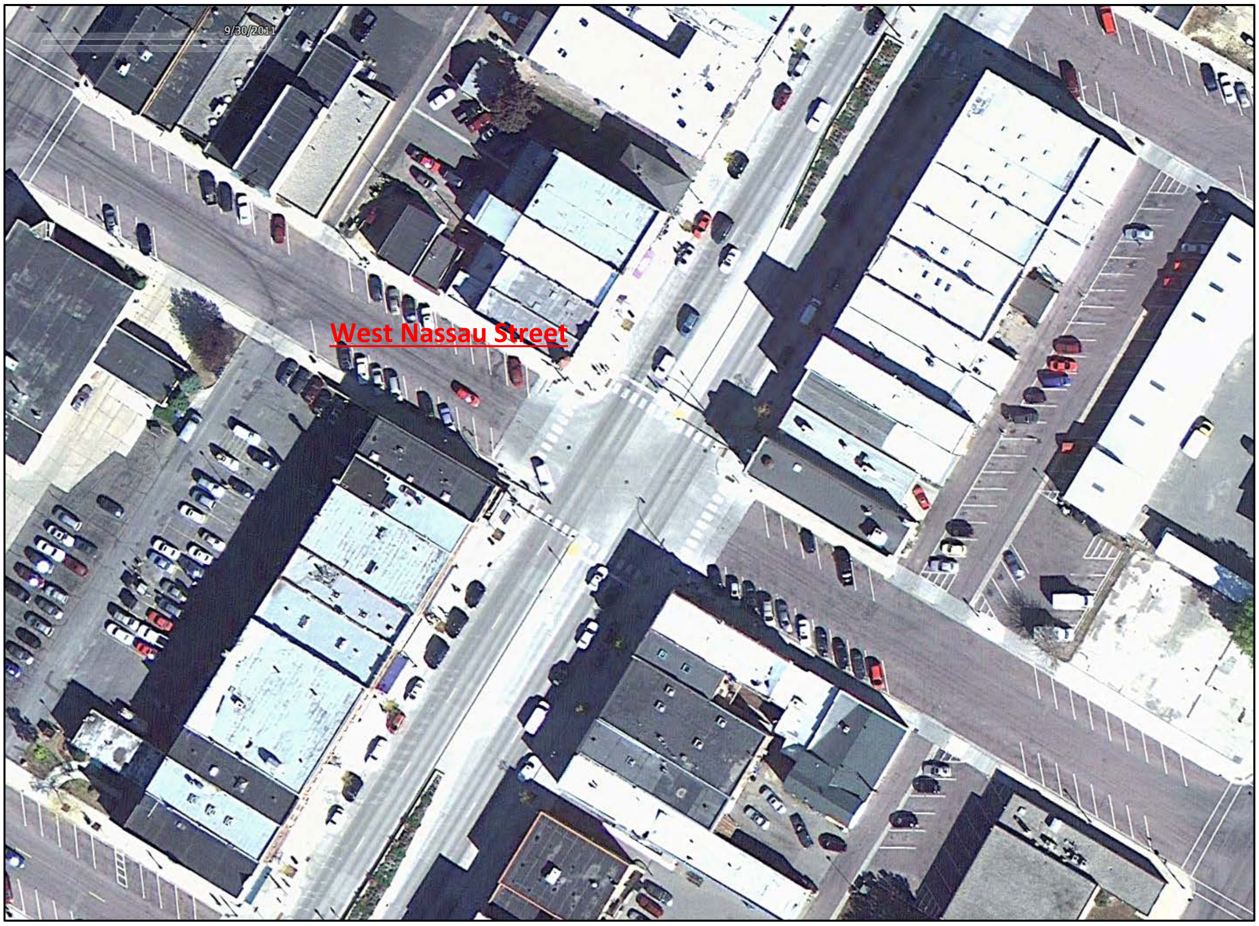

Figure 4.31: Example of TH 169 (Near West Nassau Street Intersection) After Reconstruction Showing Raised Medians, Exclusive Left-Turn Lanes and Parking Improvements

Source: Google Earth 6.2.2.6613. (September, 2011). TH 169 and West Nassau Street, 93°57'26.46"W, 44°19'26.43"N, Elevation 1532 ft. http://www.google.com/earth/index.html (Accessed 12 July, 2012).

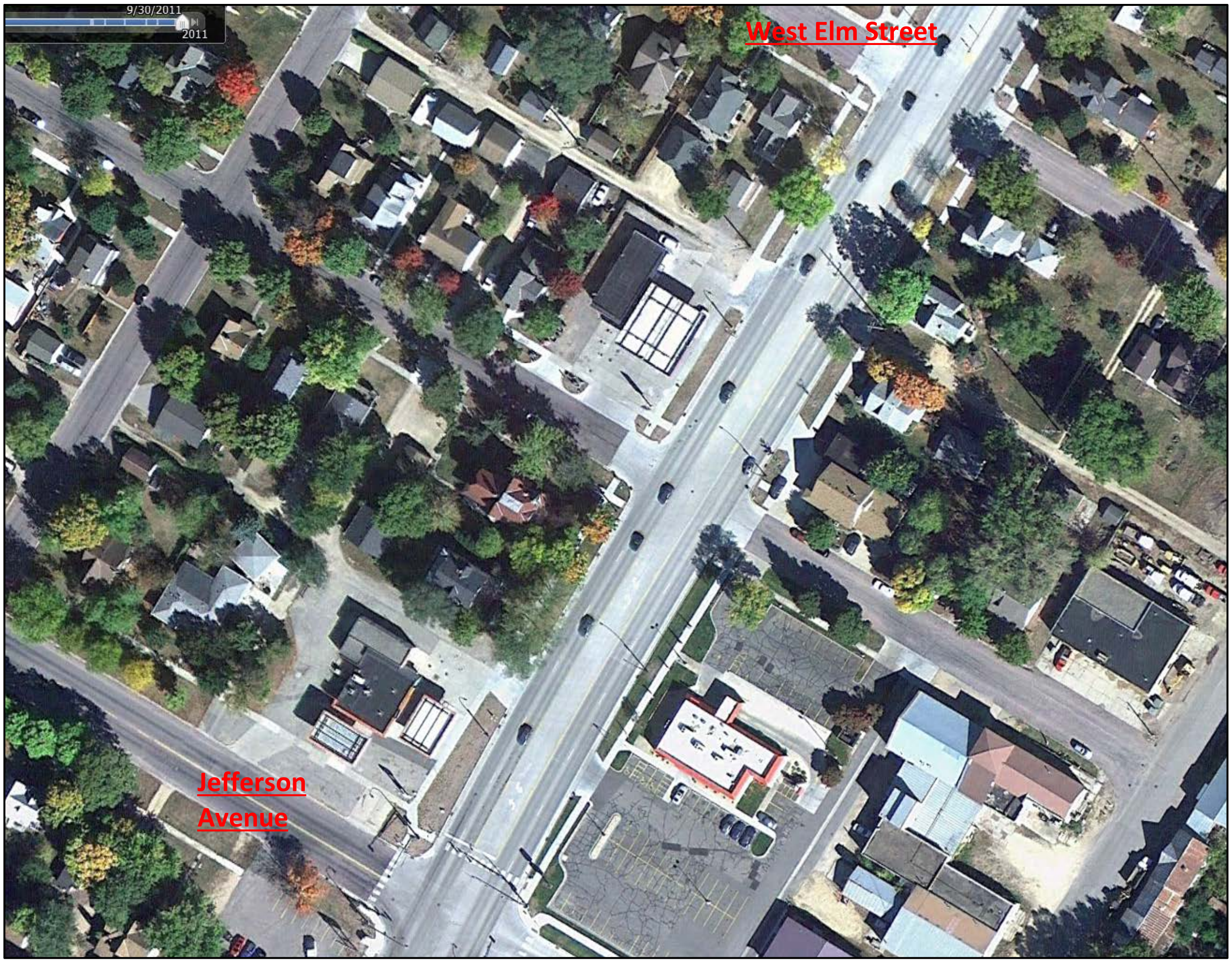

Figure 4.32: TH 169 Between Jefferson Avenue and West Elm Street After Reconstruction Showing Two-Way Left-Turn Lane Improvements

Source: Google Earth 6.2.2.6613. (September, 2011). TH 169, 93°57'48.26"W, 44°18'57.57"N, Elevation 1830 ft. http://www.google.com/earth/index.html (Accessed 12 July, 2012).

Figure 4.33: TH 169 Between West Elm Street and West Walnut Street After Reconstruction Showing Raised Median and Exclusive Left-Turn Lane Improvements

Source: Google Earth 6.2.2.6613. (September, 2011). TH 169, 93°57'38.76"W, 44°19'08.55"N, Elevation 1830 ft. http://www.google.com/earth/index.html (Accessed 12 July, 2012).

4.2.7.2 Crash Data Analysis

Safety evaluation of reconstruction work at TH 169 was conducted using 3.0 and 1.2 years of before and after crash data, respectively. Table 4.11 presents data on AADT and total number of crashes at the site in periods prior to and after the reconstruction. Detailed before-after crash analysis results using simple and EB methods is presented in Table 4.12.

Table 4.11: Crash Data for TH 169 Study Area

TH 169 (TH 22 to Union Street)		
	Before (2009) (Crashes 2007 - 2009)	After 2011 (Crashes 2011 - 2012)
	3 years	1.2 years
Segment Length	1.6 Miles	
ADT	19,900 – 22,600	15,600 – 19,700
Speed Limit	30 MPH	30 MPH
Total Crashes	90	31
FI	18	5
PDO	72	26
Rear-end	40	18
Head-on	0	0
Angle	23	8
Sideswipe, same direction	10	1
Sideswipe, opposite direction	0	1
Driveway-related	0	0
Other multiple-vehicle	1	2
Collision with animal	3	0
Collision with fixed object	6	1
Collision with other object	4	0
Other single-vehicle	3	0
Bicycle Crashes	1	0
Pedestrian Crashes	0	0

It should be noted that the crash data available in the after period was less than ideal; therefore caution should be used in interpreting the results. The results of simple before-after and EB analysis of crash types shows a decrease in the number of angle and sideswipe-same direction crashes after reconstruction of TWLTL and median improvements. However the results show an increase in rear-end crashes. There was only one sideswipe-opposite direction crash in the after period as compared to none in the before period. Overall, the results show a decrease in the number and severity of crashes and no adverse safety effects as a result of the changes implemented at this location.

There were no pedestrian crashes reported in either the before or after periods and only one bicycle crash in the before period.

Table 4.12: Summary Results of Simple and EB Before-After Crash Analysis - TH 169

Before-After Analysis by Crash Type						
	Simple Before-After Analysis			Empirical Bayes Analysis		
Crash Type	Observed Crashes - Before Period (per year)	Observed Crashes - After Period with Treatment (per year)	Percent Change (%)	Expected Average Crashes - After Period W/O Treatment (Per Year)	Crashes Reduced (or increased) in After Period (Expected - Observed)	Percent Change using Expected Average Crashes - After Period W/O Treatment Compared with Observed Crashes - After Period with Treatment (%)
When interpreting the results, caution should be used when crashes per year are less than 0.5 or less than 2 year of crash data is available						
Multiple Vehicles						
Rear End	13.3	14.4	**8.3**	13.7	-0.8	**5.8**
Head On	0.0	0.0	**0.0**	0.0	0.0	**0.0**
Angle	7.7	6.4	**-16.3**	7.6	1.2	**-15.6**
Sideswipe - Same Direction	3.3	0.8	**-75.9**	2.8	2.0	**-71.8**
Sideswipe Opposite Direction	0.0	0.8	**100.0**	0.0	-0.8	**100.0**
Other Multiple Vehicle	0.3	1.6	**381.3**	0.3	-1.4	**537.9**
Driveway Related	0.0	0.0	**0.0**	0.4	0.4	**-100.0**
Single Vehicle						
Animal Crash	1.0	0.0	**-100.0**	0.7	0.7	**-100.0**
Fixed Object Crash	2.0	0.8	**-59.9**	1.5	0.7	**-46.4**
Other Object Crash	1.3	0.0	**-100.0**	0.9	0.9	**-100.0**
Other Single Vehicle Crash	1.0	0.0	**-100.0**	0.7	0.7	**-100.0**
Total	30.0	24.9	**-17.1**	28.5	3.6	**-12.8**

Before-After Analysis by Crash Severity						
	Simple Before-After Analysis			Empirical Bayes Analysis		
Crash Severity	Observed Crashes - Before Period (per year)	Observed Crashes - After Period with Treatment (per year)	Percent Change (%)	Expected Average Crashes - After Period W/O Treatment (Per Year)	Crashes Reduced (or increased) in After Period (Expected - Observed)	Percent Change using Expected Average Crashes - After Period W/O Treatment Compared with Observed Crashes - After Period with Treatment (%)
FI	6.0	4.0	**-33.2**	7.5	3.5	**-46.4**
PDO	24.0	20.9	**-13.1**	21.0	0.2	**-0.8**
Total	30.0	24.9	**-17.1**	28.5	3.6	**-12.8**

Simple Before-After Analysis - Bike and Pedestrian Crashes Only			
Crash Type	Observed Crashes - Before Period (per year)	Observed Crashes - After Period with Treatment (per year)	Percent Change (%)
Bike Crashes	0.33	0.00	**-100.0**
Pedestrian Crashes	0.00	0.00	**0.0**
Grand Total	0.33	0.00	**-100.0**

4.2.8 Hennepin / 1st Avenues (8th St. to N. Washington Ave.), Minneapolis, MN

Between 8th Street and North Washington Avenue, segments of Hennepin Avenue and 1st Avenue North run parallel to each other as seen in Figure 4.34. Each segment is approximately 0.5 miles in length and classified as an arterial. Both segments have a posted speed limit of 30 miles per hour and there are Metro Transit bus stops as well as a light rail platform in the study area (four bus stops on Hennepin Avenue, two bus stops on 1st Avenue, one bus stop on N. 7th Street, and the light rail platform on 5th Street North). This is the most urban area examined in this research and it lies in the central business district of downtown Minneapolis.

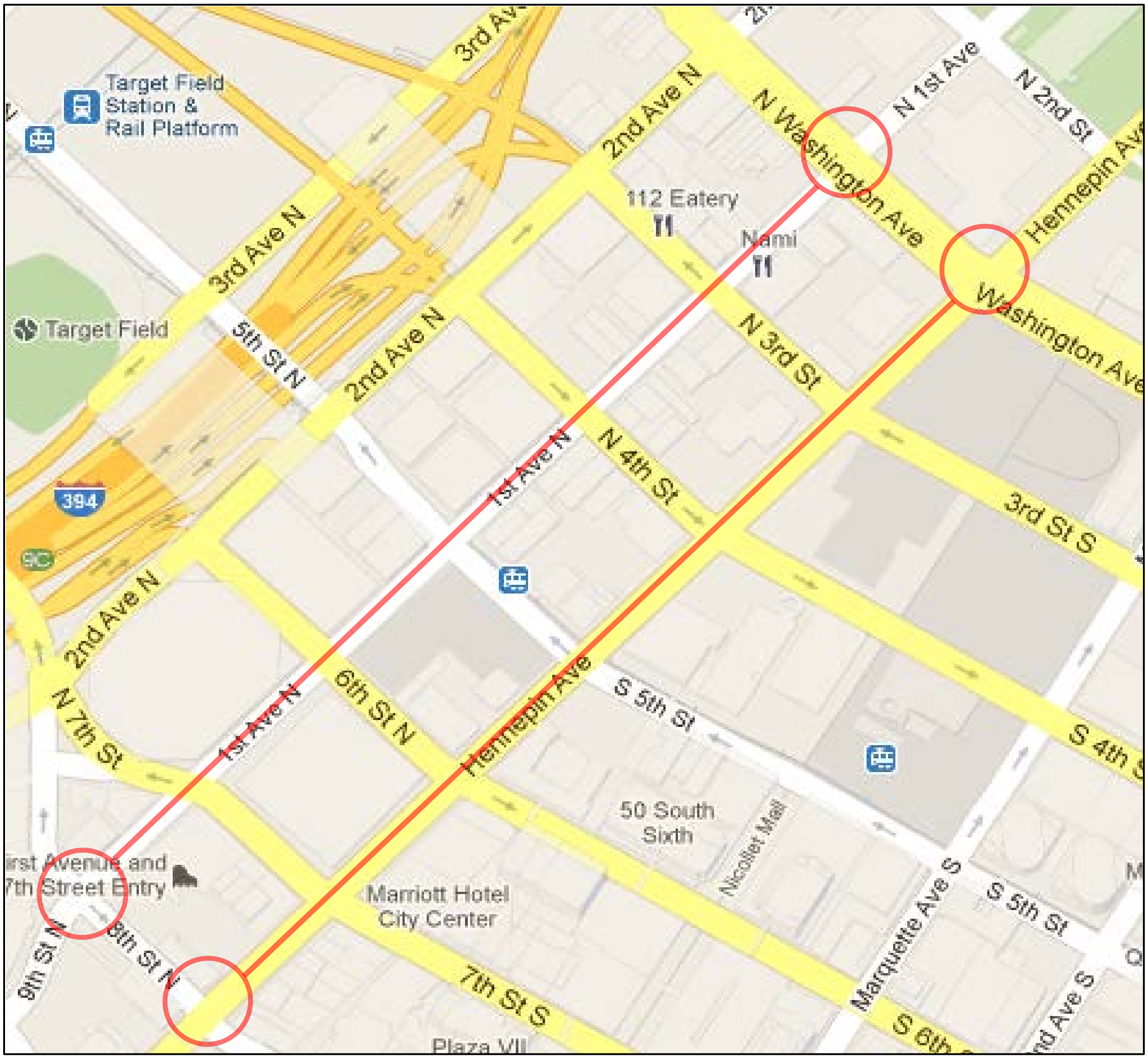

Figure 4.34: Hennepin / 1st Avenues Study Area

Source: Google Maps. http://www.google.com/maps (Accessed 12 July, 2012).

<u>4.2.8.1 Conditions Before and After Reconstruction</u>

Figure 4.35 and Figure 4.36 show the conditions before reconstruction on Hennepin Avenue and 1st Avenue, respectively. Both Hennepin Avenue and 1st Avenue operated with one-way traffic

with three one-way travel lanes. Hennepin Avenue had parking on one side, while 1st Avenue allowed parking on both sides. The other side on Hennepin Avenue was used for a two-way bicycle facility as well as a bus lane. Access points primarily consisted of a limited number of commercial driveways, many of which lead to off-street parking.

Figure 4.35: Example of Hennepin Avenue Cross-Section One-Way Configuration Before Reconstruction

Source: Google Earth 6.2.2.6613. (June, 2009). Hennepin Avenue, 93°16'19.78"W, 44°58'45.64"N, Elevation 860 ft. http://www.google.com/earth/index.html (Accessed 12 July, 2012).

Figure 4.36: Example of 1st Avenue Cross-Section One-Way Configuration Before Reconstruction

Source: Google Earth 6.2.2.6613. (July, 2009). Hennepin Avenue, 93°16'26.32"W, 44°58'48.60"N, Elevation 860 ft. http://www.google.com/earth/index.html (Accessed 12 July, 2012).

Construction took place from 2009 to 2010 to convert the existing segments from their previous configuration of one-way streets with parking to two-way facilities, details of which are described in the following and are illustrated in Figure 4.37 and Figure 4.38 for Hennepin Avenue and 1st Avenue, respectively.

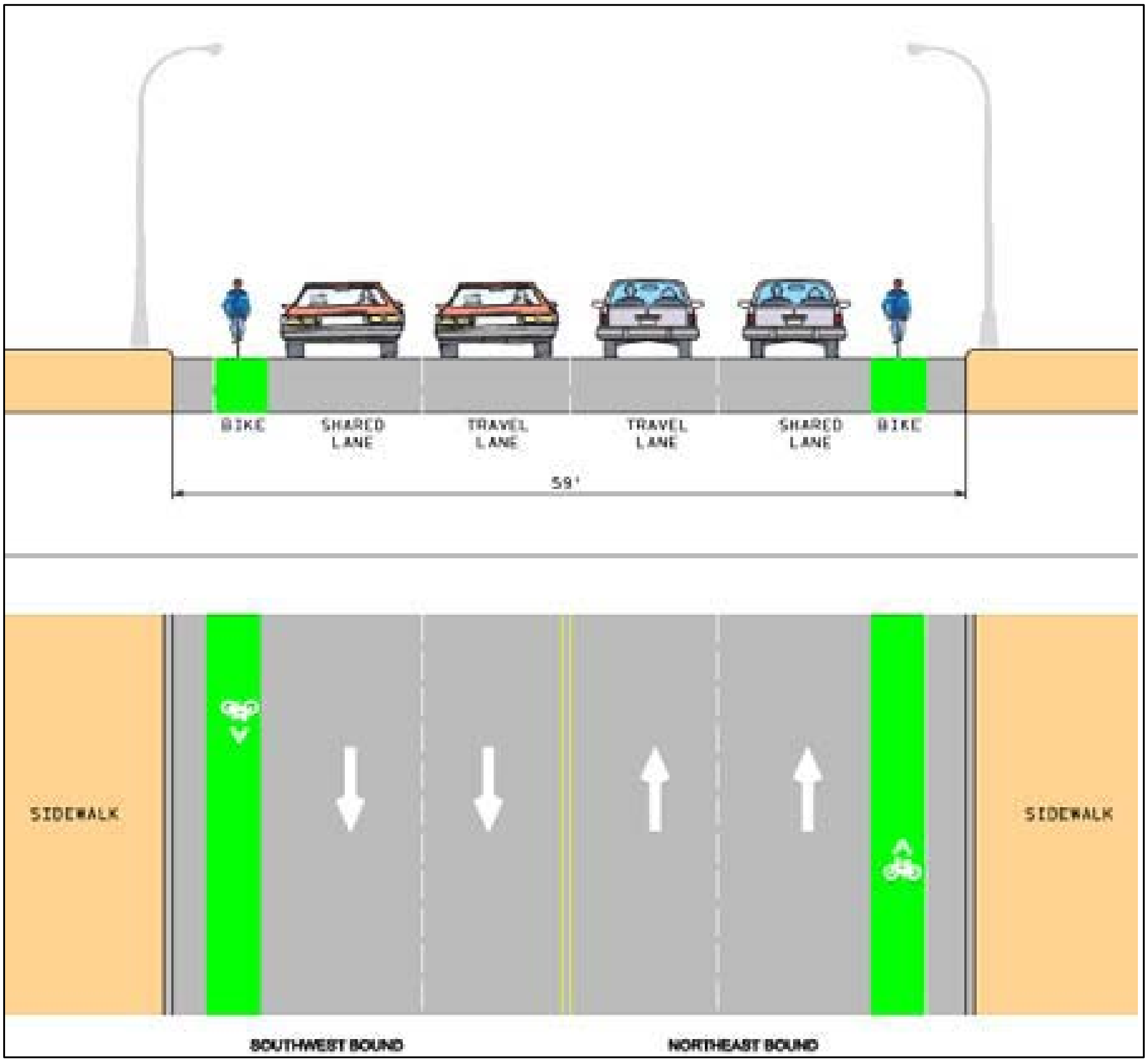

Figure 4.37: Example of Hennepin Avenue Proposed Cross-Section After Reconstruction
Source: City of Minneapolis, MN

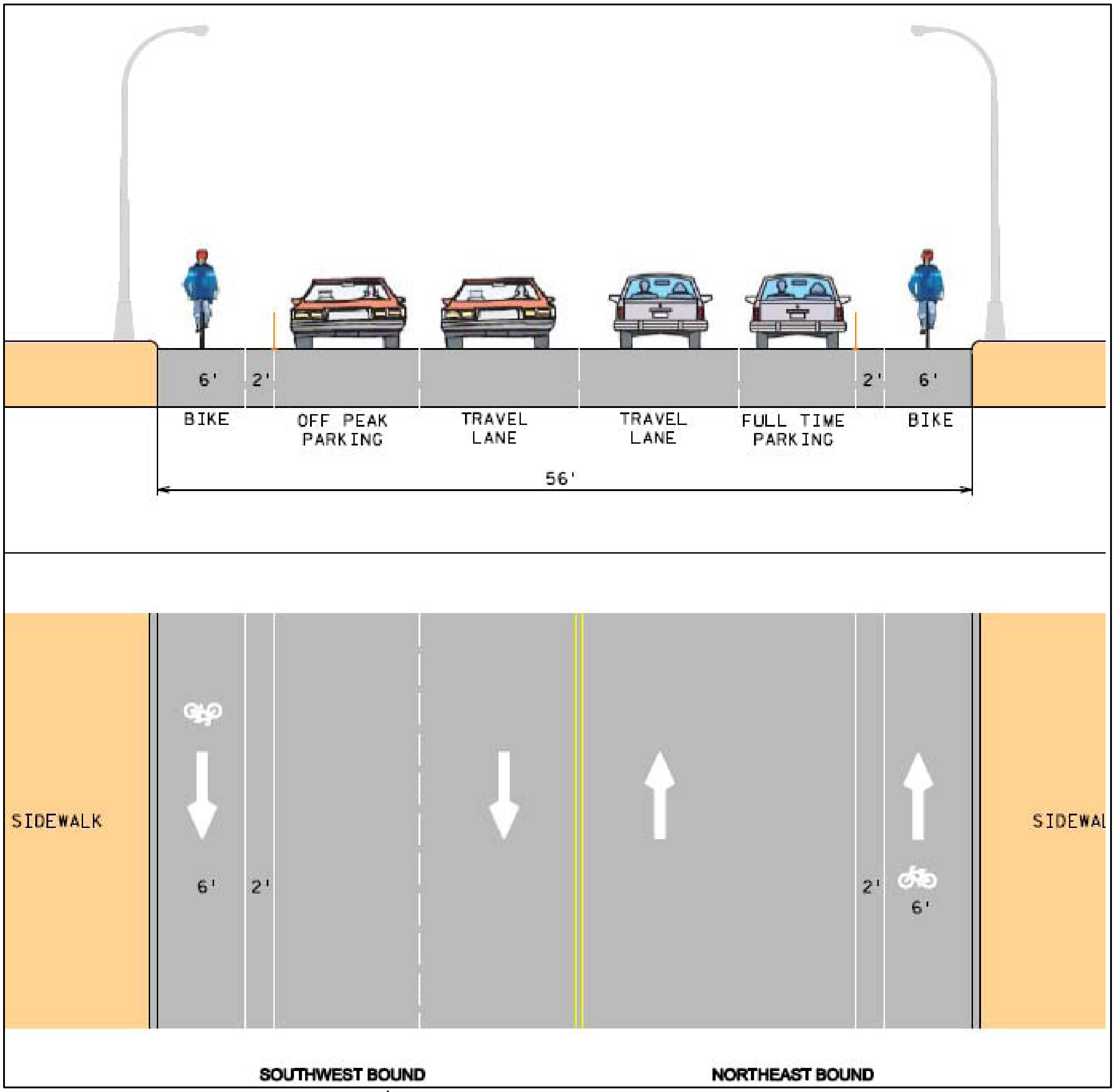

Figure 4.38: Example of 1st Avenue Proposed Cross-Section After Reconstruction

Source: City of Minneapolis, MN

After reconstruction, both facilities had cross-sections that incorporated two travel/parking lanes (in varying combinations) and one bicycle lane in each direction. Bicycle lanes are 6 feet wide and separated from travel or parking lanes by one of two different methods. On 1st Avenue, bicycle lanes are separated from the travel lanes by 2 feet of space. In the case of Hennepin Avenue, delineated bicycle lanes were overlaid with 4 feet wide green paint to increase conspicuity which is shown in Figure 4.39. In addition to differences in the way bicycle facilities are laid out, Hennepin Avenue and 1st Avenue also use the outer lanes in their respective cross-sections differently. On Hennepin Avenue, the outermost lane in each direction of travel is a shared lane allowing for dual usage by vehicles and bicyclists. On 1st Avenue, the outermost lane in the northeast-bound direction is used as a dedicated parking lane, while the outermost lane in the southwest-bound direction is used for parking during off-peak hours only.

Figure 4.40 shows bicycle lanes and other improvements after reconstruction on 1st Avenue. Exclusive left-turn lanes were also added in locations where volumes warranted them, such as the intersection of Hennepin Avenue and Washington Avenue. No new pedestrian accommodations were constructed in this project. Rather, the existing sidewalk facilities on both sides of each street remained the same as before reconstruction.

Figure 4.39: Example of Hennepin Avenue Bicycle Lane After Reconstruction

Source: City of Minneapolis, MN

Figure 4.40: Example of 1st Avenue Bicycle Lanes and Other Improvements After Reconstruction

Source: Google Maps. http://www.google.com/maps (Accessed 12 July, 2012).

4.2.8.2 Crash Data Analysis

Safety evaluation of reconstruction work at Hennepin Avenue and 1st Avenue was conducted using 2.1 and 1.1 years of before and after crash data, respectively. Table 4.13 and Table 4.14 presents data on AADT and total number of crashes at the site in periods prior to and after the reconstruction. Detailed before-after crash analysis results using simple method are presented in Table 4.15 and Table 4.16.

Table 4.13: Crash Data for Hennepin Avenue Study Area

Hennepin Avenue (Washington Avenue to 8th Street)		
	Before (2008) (Crashes Sept. 2007 - Sept. 2009)	After (2010) (Crashes Sept. 2010-2011)
	2.1 years	1.1 years
Segment Length	1.0 mile	
ADT	9,400 – 21,900	9,400 – 21,900
Speed Limit	30 MPH	30 MPH
Total Crashes	118	30
FI	28	11
PDO	90	19
Rear-end	44	12
Head-on	0	2
Angle	31	6
Sideswipe, same direction	28	8
Sideswipe, opposite direction	2	1
Driveway-related	1	0
Other multiple-vehicle	7	1
Collision with animal	0	0
Collision with fixed object	2	0
Collision with other object	3	1
Other single-vehicle	1	0
Bicycle Crashes	23	3
Pedestrian Crashes	11	2

Table 4.14: Crash Data for 1st Avenue Study Area

1st Avenue (8th Street to Washington Avenue)		
	Before (2008) (Crashes Sept. 2007 - Sept. 2009)	After (2010) (Crashes Dec. 2009 -2011)
	2.1 years	1 year
Segment Length	1.0 mile	
ADT	17700 - 23600	17700 – 23600
Speed Limit	30 MPH	30 MPH
Total Crashes	23	5
FI	4	3
PDO	19	2
Rear-end	4	1
Head-on	0	0
Angle	9	2
Sideswipe, same direction	3	1
Sideswipe, opposite direction	0	0
Driveway-related	0	0
Other multiple-vehicle	5	0
Collision with animal	0	0
Collision with fixed object	2	1
Collision with other object	0	0
Other single-vehicle	0	0
Bicycle Crashes	0	0
Pedestrian Crashes	5	0

It should be noted that the number of years of crash data available in the after period was less than ideal; therefore caution should be used in interpreting the results. EB analysis for Hennepin and 1st Avenues could not be completed because the HSM does not include SPFs for one-way roads. The result of simple before-after analysis of crash types for Hennepin Avenue shows a decrease in the number of crashes after reconstruction. The only increase was 2 head-on crashes as compared to none in the before period which was likely due to the directional conversion of the street. Simple before-after analysis results of crash types for 1st Avenue shows a decrease in all crashes with the exception of a slight increase in single vehicle fixed object crashes.

Crash severity analysis for both road segments shows a decrease in severity of crashes on Hennepin Avenue but an increase in FI crashes on 1st Avenue. However, since only 1 year of after crash data is available, no definite conclusions can be made. Bicycle and pedestrian crashes have also been reduced after reconstruction work; however, there were no bicycle crashes at 1st Avenue in the before or after periods. Overall, the results show that the improvements made at Hennepin and 1st Avenues were able to reduce the number and severity of vehicle and bicycle/pedestrian crashes.

Table 4.15: Summary Results of Simple and EB Before-After Crash Analysis - Hennepin Avenue

Before-After Analysis by Crash Type

	Simple Before-After Analysis			Empirical Bayes Analysis		
Crash Type	Observed Crashes - Before Period (per year)	Observed Crashes - After Period with Treatment (per year)	Percent Change (%)	Expected Average Crashes - After Period W/O Treatment (Per Year)	Crashes Reduced (or increased) in After Period (Expected - Observed)	Percent Change using Expected Average Crashes - After Period W/O Treatment Compared with Observed Crashes - After Period with Treatment (%)
When interpreting the results, caution should be used when crashes per year are less than 0.5 or less than 2 year of crash data is available						
Multiple Vehicles						
Rear End	21.1	11.1	**-47.4**	N/A		
Head On	0.0	1.9	**100.0**			
Angle	14.9	5.6	**-62.7**			
Sideswipe - Same Direction	13.4	7.4	**-44.9**			
Sideswipe Opposite Direction	1.0	0.9	**-3.6**			
Other Multiple Vehicle	3.4	0.9	**-72.4**			
Driveway Related	0.5	0.0	**-100.0**			
Single Vehicle						
Animal Crash	0.0	0.0	**0.0**	N/A		
Fixed Object Crash	1.0	0.0	**-100.0**			
Other Object Crash	1.4	0.9	**-35.7**			
Other Single Vehicle Crash	0.5	0.0	**-100.0**			
Total	57.2	28.7	**-49.8**			

Before-After Analysis by Crash Severity

	Simple Before-After Analysis			Empirical Bayes Analysis		
Crash Severity	Observed Crashes - Before Period (per year)	Observed Crashes - After Period with Treatment (per year)	Percent Change (%)	Expected Average Crashes - After Period W/O Treatment (Per Year)	Crashes Reduced (or increased) in After Period (Expected - Observed)	Percent Change using Expected Average Crashes - After Period W/O Treatment Compared with Observed Crashes - After Period with Treatment (%)
FI	13.4	10.2	**-24.2**	N/A		
PDO	43.2	17.6	**-59.3**			
Total	56.7	27.8	**-51.0**			

Simple Before-After Analysis - Bike and Pedestrian Crashes Only

Crash Type	Observed Crashes - Before Period (per year)	Observed Crashes - After Period with Treatment (per year)	Percent Change (%)
Bike Crashes	11.05	2.78	**-74.8**
Pedestrian Crashes	5.28	1.85	**-64.9**
Grand Total	16.33	4.63	**-71.6**

Table 4.16: Summary Results of Simple and EB Before-After Crash Analysis - 1st Avenue

Before-After Analysis by Crash Type						
	Simple Before-After Analysis			Empirical Bayes Analysis		
Crash Type	Observed Crashes - Before Period (per year)	Observed Crashes - After Period with Treatment (per year)	Percent Change (%)	Expected Average Crashes - After Period W/O Treatment (Per Year)	Crashes Reduced (or increased) in After Period (Expected - Observed)	Percent Change using Expected Average Crashes - After Period W/O Treatment Compared with Observed Crashes - After Period with Treatment (%)
When interpreting the results, caution should be used when crashes per year are less than 0.5 or less than 2 year of crash data is available						
Multiple Vehicles						
Rear End	1.9	1.0	**-47.9**	N/A		
Head On	0.0	0.0	**0.0**			
Angle	4.3	2.0	**-53.7**			
Sideswipe - Same Direction	1.4	1.0	**-30.6**			
Sideswipe Opposite Direction	0.0	0.0	**0.0**			
Other Multiple Vehicle	2.4	0.0	**-100.0**			
Driveway Related	0.0	0.0	**0.0**			
Single Vehicle						
Animal Crash	0.0	0.0	**0.0**	N/A		
Fixed Object Crash	1.0	1.0	**4.1**			
Other Object Crash	0.0	0.0	**0.0**			
Other Single Vehicle Crash	0.0	0.0	**0.0**			
Total	11.0	5.0	**-54.7**			

Before-After Analysis by Crash Severity						
	Simple Before-After Analysis			Empirical Bayes Analysis		
Crash Severity	Observed Crashes - Before Period (per year)	Observed Crashes - After Period with Treatment (per year)	Percent Change (%)	Expected Average Crashes - After Period W/O Treatment (Per Year)	Crashes Reduced (or increased) in After Period (Expected - Observed)	Percent Change using Expected Average Crashes - After Period W/O Treatment Compared with Observed Crashes - After Period with Treatment (%)
FI	1.9	3.0	**56.2**	N/A		
PDO	9.1	2.0	**-78.1**			
Total	11.0	5.0	**-54.7**			

Simple Before-After Analysis - Bike and Pedestrian Crashes Only			
Crash Type	Observed Crashes - Before Period (per year)	Observed Crashes - After Period with Treatment (per year)	Percent Change (%)
Bike Crashes	0.00	0.00	0.0
Pedestrian Crashes	2.40	0.00	-100.0
Grand Total	2.40	0.00	-100.0

4.2.9 Williamson Street (S. Blount St. to S. Baldwin St.), Madison, WI

Williamson Street is located in Madison, WI but has very similar characteristics to the other study areas located in Minnesota. The study area selected for analysis involves the stretch of roadway from South Blount Street to South Baldwin Street shown in Figure 4.41. The segment is approximately 0.7 miles in length, has a posted speed limit of 30 miles per hour, and is classified as an arterial. Williamson St. has a mix of both small businesses and residential property; hence, the degree of access varies, although it is significantly less than residential areas in which each home has its own driveway. Although there are no metro transit bus stops on this segment of Williamson Street, there are many on the adjacent portion of Jennifer Street which is residential.

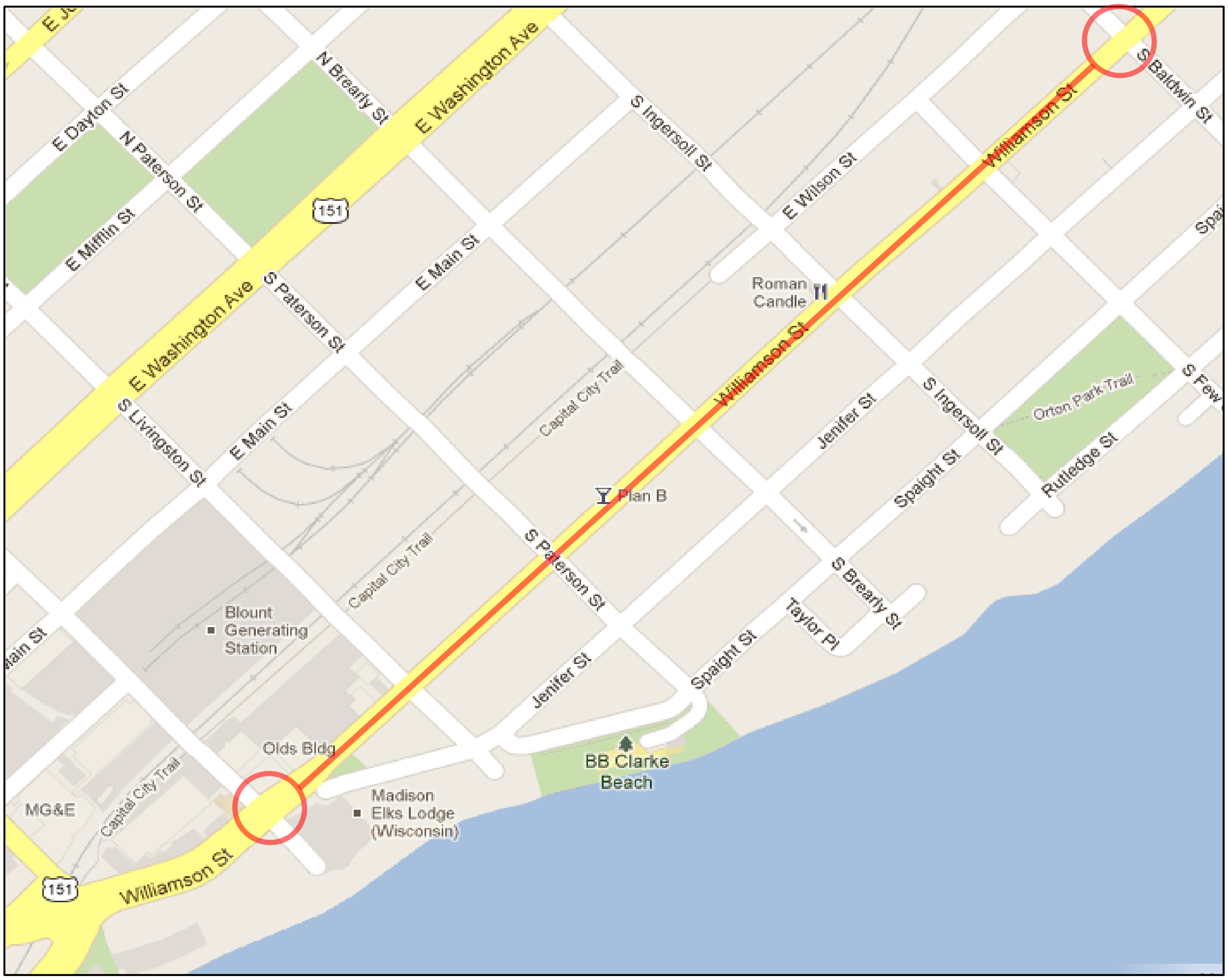

Figure 4.41: Williamson Street Study Area

Source: Google Maps. http://www.google.com/maps (Accessed 12 July, 2012).

4.2.9.1 Conditions Before and After Reconstruction

Reconstruction took place between April and October 2011 and involved the narrowing of the pre-existing 48 foot wide roadway to 44 feet. Although the layout of one through lane and one parking lane in each direction of travel was maintained, all lane widths were decreased by 1 foot; the width of travel lanes was reduced from 11 feet to 10 feet and parking lane width was reduced from 13 feet to 12 feet. The 4 available feet of roadway was allocated to providing two additional feet of terrace space on each side of the road. Figure 4.42 presents a typical example of the cross-section after reconstruction. Sidewalks on both sides of the street were reconstructed although their widths did not change. Figures 4.43 and 4.44 illustrate the conditions before and after reconstruction in the vicinity of Williamson Street and Blount Street, showing the reduction of lane widths and addition of bicycle lanes for a small section of the segment only.

Figure 4.42: Williamson Street Cross-Section Following Reconstruct with Widened Terraces

Figure 4.43: Intersection of Williamson Street and Blount Street Before Reconstruction and Reduction in Lane Width

Source: Google Earth 6.2.2.6613. (May, 2010). Williamson Street and Blount Street Intersection, 89°22'20.81"W, 43°04'38.94"N, Elevation 1629 ft. http://www.google.com/earth/index.html (Accessed 28 September, 2012).

Figure 4.44: Intersection of Williamson Street and Blount Street After Reconstruction Showing Reduction in Lane Width and Addition of Bicycle Lanes

4.2.9.2 Crash Data Analysis

Safety evaluation of reconstruction work at Williamson Street was conducted using 3.0 and 0.9 years of before and after crash data, respectively. Table 4.17 presents data on AADT and total number of crashes at the site in periods prior to and after the reconstruction. Detailed before-after crash analysis results using simple and EB methods is presented in Table 4.18.

Table 4.17: Crash Data for Williamson Street Study Area

Williamson St (S. Blount St. to S. Baldwin St.)		
	Before (Mar. 2006- Apr. 2011)	After 2011 (Oct. 2011- Dec. 2011)
	3 years	0.9 years
Segment Length	0.9 Miles	
ADT	16,850-21,500	16,850-21,500
Speed Limit	30 MPH	30 MPH
Total Crashes	75	20
FI	23	4
PDO	52	16
Rear-end	45	11
Head-on	0	0
Angle	13	1
Sideswipe, same direction	10	5
Sideswipe, opposite direction	1	0
Driveway-related	0	0
Other multiple-vehicle	2	0
Collision with animal	0	0
Collision with fixed object	2	1
Collision with other object	1	0
Other single-vehicle	1	2
Bicycle Crashes	3	0
Pedestrian Crashes	0	0

It should be noted that the number of years of crash data available in the after period was less than 2 years; therefore caution should be used in interpreting the results. The results of simple before-after and EB analysis of crash types shows a general decrease in the number of crashes after reconstruction with the exception of sideswipe-same direction crashes. Increases in single vehicle crashes are inconclusive because there are two or less crashes in each case. The result of crash severity analysis shows decrease in FI crashes but a slight increase in PDO crashes. Overall, the results suggest that the changes made at this section of Williamson Street, especially reduction in lane width, did not result in any adverse safety impacts, rather the overall number and severity was reduced.

Analysis of bicycle and pedestrian crashes shows a decrease in the number of bicycle crashes from 3 to 0; however, caution should be used because of the lack of enough data in the after period. There were no pedestrian crashes in the before or after periods.

Table 4.18: Summary Results of Simple and EB Before-After Crash Analysis - Williamson Street

Before-After Analysis by Crash Type						
	Simple Before-After Analysis			Empirical Bayes Analysis		
Crash Type	Observed Crashes - Before Period (per year)	Observed Crashes - After Period with Treatment (per year)	Percent Change (%)	Expected Average Crashes - After Period W/O Treatment (Per Year)	Crashes Reduced (or increased) in After Period (Expected - Observed)	Percent Change using Expected Average Crashes - After Period W/O Treatment Compared with Observed Crashes - After Period with Treatment (%)
When interpreting the results, caution should be used when crashes per year are less than 0.5 or less than 2 year of crash data is available						
Multiple Vehicles						
Rear End	15.0	12.0	**-19.8**	14.9	2.9	**-19.4**
Head On	0.0	0.0	**0.0**	0.0	0.0	**0.0**
Angle	4.3	1.1	**-74.8**	3.7	2.6	**-70.2**
Sideswipe - Same Direction	3.3	5.5	**64.1**	2.7	-2.8	**103.7**
Sideswipe Opposite Direction	0.3	0.0	**-100.0**	0.2	0.2	**-100.0**
Other Multiple Vehicle	0.7	0.0	**-100.0**	0.4	0.4	**-100.0**
Driveway Related	0.0	0.0	**0.0**	1.2	1.2	**-100.0**
Single Vehicle						
Animal Crash	0.0	0.0	**0.0**	0.0	0.0	**0.0**
Fixed Object Crash	0.7	1.1	**64.1**	0.9	-0.2	**20.7**
Other Object Crash	0.3	0.0	**-100.0**	0.5	0.5	**-100.0**
Other Single Vehicle Crash	0.3	2.2	**556.3**	0.5	-1.7	**346.0**
Total	25.0	21.9	**-12.5**	24.9	3.0	**-12.2**

Before-After Analysis by Crash Severity						
	Simple Before-After Analysis			Empirical Bayes Analysis		
Crash Severity	Observed Crashes - Before Period (per year)	Observed Crashes - After Period with Treatment (per year)	Percent Change (%)	Expected Average Crashes - After Period W/O Treatment (Per Year)	Crashes Reduced (or increased) in After Period (Expected - Observed)	Percent Change using Expected Average Crashes - After Period W/O Treatment Compared with Observed Crashes - After Period with Treatment (%)
FI	7.7	4.4	**-42.9**	7.8	3.5	**-44.1**
PDO	17.3	17.5	**1.0**	17.1	-0.4	**2.4**
Total	25.0	21.9	**-12.5**	24.9	3.0	**-12.2**

Simple Before-After Analysis - Bike and Pedestrian Crashes Only			
Crash Type	Observed Crashes - Before Period (per year)	Observed Crashes - After Period with Treatment (per year)	Percent Change (%)
Bike Crashes	1.00	0.00	**-100.0**
Pedestrian Crashes	0.00	0.00	**0.0**
Grand Total	1.00	0.00	**-100.0**

4.2.10 Marshall Avenue (E. Lake St. to Cretin Ave.), St. Paul, MN

The section of Marshall Avenue between the Mississippi River Bridge (MRB) (East Lake Street) and Cretin Avenue (see Figure 4.45) was reconfigured as a result of the Non-motorized Transportation Pilot Program (NTPP) defined in the Safe, Accountable, Flexible, Efficient Transportation Act: A Legacy for Users (SAFETEA-LU). The goal of the NTPP was to provide funding to communities in order to expand their "network" of facilities for non-motorized modes of transportation and in doing so, show the viability of these alternate modes. In addition to being part of the NTPP, known as Bike/Walk Twin Cities in the Minneapolis/St. Paul Area, the reconfiguration of Marshall Avenue was classified as a "Network Gap Closure" project. The idea behind a "Network Gap Closure" project is to fill the gap in bicycle and pedestrian facilities which in this case was between the Lake Street/Marshall Avenue Bridge crossing the Mississippi River and Cretin Avenue, where existing facilities for non-motorized vehicles were limited [36].

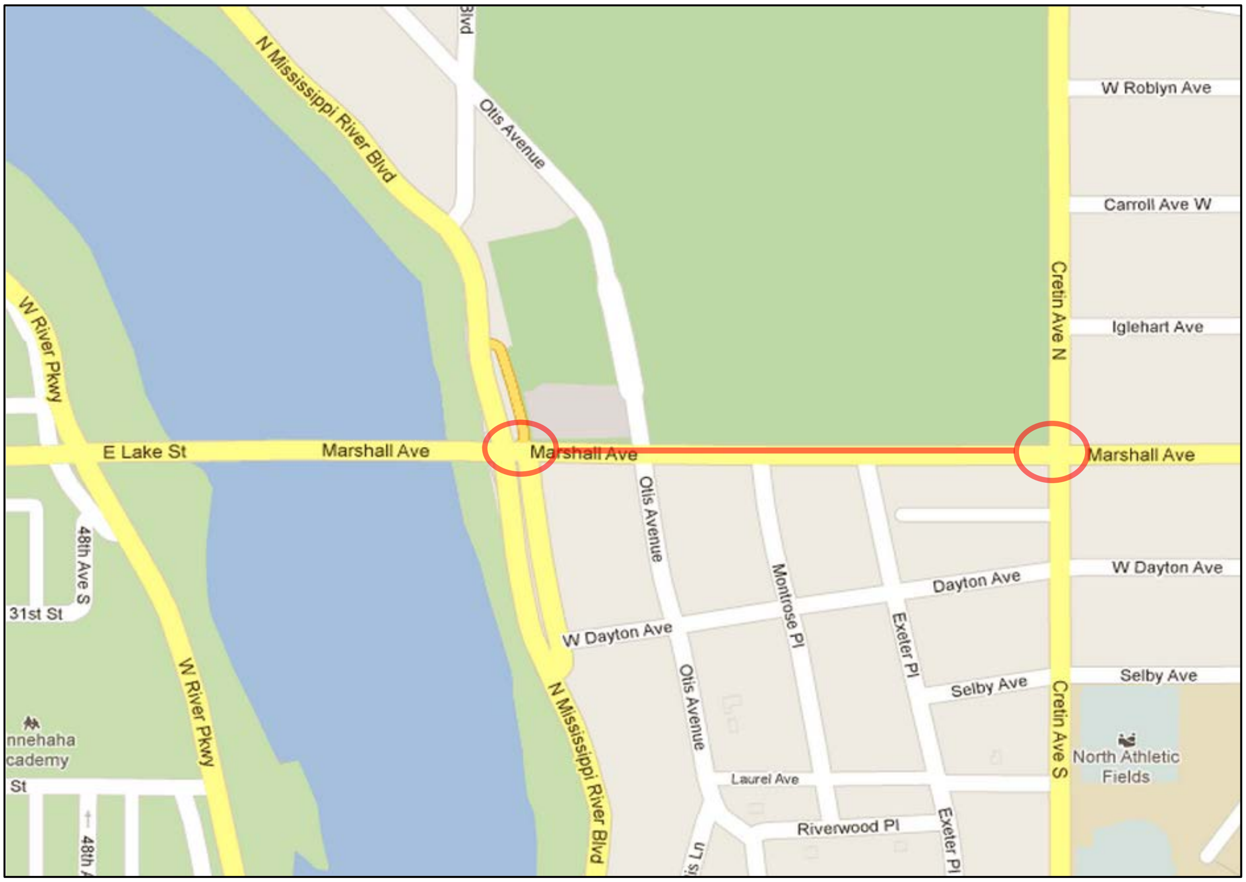

Figure 4.45: Marshall Avenue Study Area

Source: Google Maps. http://www.google.com/maps (Accessed 28 September, 2012).

The speed limit along this 0.39 mile long segment of minor arterial was 35 miles per hour and remained the same after reconstruction and access remained relatively restricted along the road with only a few driveways on the south side. The surrounding area is primarily residential, although there is a golf course on the north side of the road.

4.2.10.1 Conditions Before and After Reconstruction

Before reconstruction, the segment had four travel lanes and did not have delineated bicycle lanes or bicycle traffic control devices. Additionally, a sidewalk was only provided along the south side of the road. Pedestrians made use of a trodden path through grass on the north side of the road. After construction, which was completed in October 2010, a bicycle lane was added to Marshall Avenue in the eastbound direction and a “Bicycles May Use Full Lane” sign was added in the westbound direction, in which bicycles and other vehicles share a widened outside lane. The added bicycle facilities allowed bicyclists traveling westbound on Marshall Avenue to easily and safely access existing multi-use paths on either side of the River. Furthermore, pedestrian accommodations were improved by adding a sidewalk on the north side of Marshall Avenue as well as by upgrading crosswalks near the three Metro Transit bus stops along the segment.

In addition to the added bicycle facilities, the road was both widened and narrowed along certain segments to accommodate lane reconfiguration; the details of the lane configuration and overall roadway widths in the periods both before and after construction can be seen in Table 4.19. Figure 4.46 shows the cross-section of Marshall Avenue following the reconstruction; Figures 4.47 and 4.48 illustrate the changes before and after reconstruction in the proximity of Marshall Avenue and Cretin Avenue intersection clearly showing the addition of a bicycle lane in the eastbound direction and sidewalks north of Marshall Avenue.

Table 4.19: Mississippi River Bridge to Cretin St. Layout Description Before and After Reconstruction

Street Section	Before Conditions	After Conditions
Mississippi River Bridge to Otis Avenue	72 feet with the lane assignments as (north to south) two 13 foot through lanes, a 10 foot gore area, a 12 foot through lane, a 16 foot through lane and an 8 foot parking lane.	70 feet with the lane assignments as (north to south) 14 foot shared bicycle/vehicle through lane, one 11 foot through lane, one 10 foot turn lane, two 11 foot through lanes, a 5 foot bicycle lane and an 8 foot parking lane.
East Leg of Otis Avenue	62 feet with the lane assignments as (north to south) one 13 foot through lane, one 11 foot through lane, one 11 foot turn lane, one 14 foot through lane and one 13 foot through lane.	62 feet with one 14 foot shared bicycle/vehicle lane, one 11 foot through lane, one 10 foot turn lane, two 11 foot through lanes and a 5 foot bicycle lane.
From East Leg of Otis Avenue Cretin Avenue	56 feet with lane assignments as (north to south) two 12 foot through lanes, one 12 foot turn lane, one 12 foot through lane and an 8 foot parking lane.	58 feet with lane assignments as (north to south) one 14 foot shared bicycle/vehicle lane, on 11 foot through lane, one 10 foot turn lane, on 11 foot through lane, one 5 foot bicycle lane and a 7 foot parking lane.

Figure 4.46: Marshall Avenue Cross-Section Following Reconstruction

Figure 4.47: Marshall Avenue Section (Near Cretin Avenue Intersection) Before Reconstruction Showing No Bicycle Lane and Missing Sidewalk North of Marshall Avenue

Source: Google Earth 6.2.2.6613. (May, 2010). Marshall Avenue and Cretin Avenue intersection, 93°11'38.06"W, 44°56'53.72"N, Elevation 1629 ft. http://www.google.com/earth/index.html (Accessed 28 September, 2012).

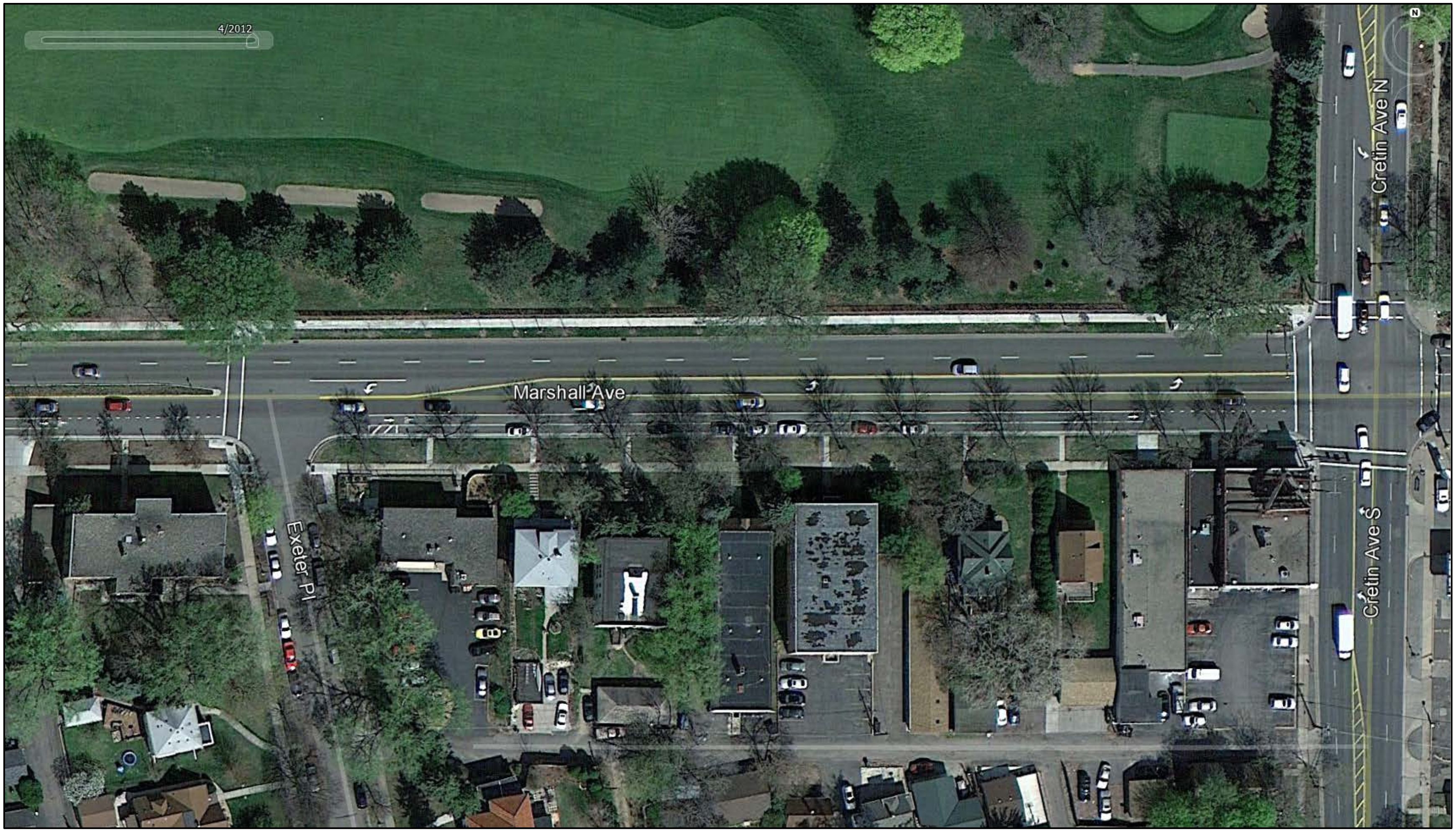

Figure 4.48: Marshall Avenue Section (Near Cretin Avenue Intersection) After Reconstruction Showing Bicycle Lane and New Sidewalk North of Marshall Avenue

Source: Google Earth 6.2.2.6613. (April, 2012). Marshall Avenue and Cretin Avenue intersection, 93°11'38.06"W, 44°56'53.72"N, Elevation 1629 ft. http://www.google.com/earth/index.html (Accessed 28 September, 2012).

4.2.10.2 Crash Data Analysis

Safety evaluation of reconstruction work at Marshall Avenue was conducted using 1 year of before and after crash data, respectively. Table 4.20 presents data on AADT and total number of crashes at the site in periods prior to and after the reconstruction. Detailed before-after crash analysis results using simple and EB methods is presented in Table 4.21.

Table 4.20: Crash Data for Marshall Avenue Study Area

Marshall Ave. (Mississippi River Bridge to Cretin Ave.)		
	Before 2008 (2008 - 2009)	After 2011 (Oct. 2010- 2011)
	1 year	1 year
Segment Length	0.39 Miles	
ADT	12,600 – 17,400	13,100 – 19,000
Speed Limit	35 MPH	35 MPH
Total Crashes	42	41
FI	3	9
PDO	39	32
Rear-end	17	21
Head-on	2	1
Angle	11	9
Sideswipe, same direction	1	6
Sideswipe, opposite direction	0	0
Driveway-related	2	0
Other multiple-vehicle	2	2
Collision with animal	0	0
Collision with fixed object	4	2
Collision with other object	3	0
Other single-vehicle	0	0
Bicycle Crashes	3	5
Pedestrian Crashes	1	1

It is difficult to make conclusions about specific safety impacts at this location because the number of years of crash data available in the before and after period was less than two; therefore, caution should be used in interpreting the results. The results of simple before-after and EB analysis show increases in certain types of crashes. Crash severity analysis also shows an increase in FI crashes and reduction in PDO crashes.

Bicycle crashes have increased from three to five which could be due to increased bicycle traffic after the addition of bicycle lanes. However, again it is difficult to draw definite conclusions in the absence of before and after bicycle counts. It should also be noted that the percentages are exaggerated in some cases because only one year of crash data was available. Overall, it is unclear whether the resulting increase in crashes is a complete random or indicative of a systematic problem given the lack of more years or crash data.

Table 4.21: Summary Results of Simple and EB Before-After Crash Analysis - Marshall Avenue

Before-After Analysis by Crash Type						
	Simple Before-After Analysis			Empirical Bayes Analysis		
Crash Type	Observed Crashes - Before Period (per year)	Observed Crashes - After Period with Treatment (per year)	Percent Change (%)	Expected Average Crashes - After Period W/O Treatment (Per Year)	Crashes Reduced (or increased) in After Period (Expected - Observed)	Percent Change using Expected Average Crashes - After Period W/O Treatment Compared with Observed Crashes - After Period with Treatment (%)
When interpreting the results, caution should be used when crashes per year are less than 0.5 or less than 2 year of crash data is available						
Multiple Vehicles						
Rear End	17.0	21.1	**23.5**	15.7	-5.4	**34.4**
Head On	2.0	1.0	**-50.0**	0.5	-0.5	**103.7**
Angle	11.0	9.0	**-18.2**	7.2	-1.9	**25.9**
Sideswipe - Same Direction	1.0	6.0	**500.0**	0.2	-5.8	**3362.9**
Sideswipe Opposite Direction	0.0	0.0	**0.0**	0.0	0.0	**0.0**
Other Multiple Vehicle	2.0	2.0	**0.0**	1.1	-0.9	**80.6**
Driveway Related	2.0	0.0	**-100.0**	1.6	1.6	**-100.0**
Single Vehicle						
Animal Crash	0.0	0.0	**0.0**	0.0	0.0	**0.0**
Fixed Object Crash	4.0	2.0	**-50.0**	2.0	0.0	**2.2**
Other Object Crash	3.0	0.0	**-100.0**	1.1	1.1	**-100.0**
Other Single Vehicle Crash	0.0	0.0	**0.0**	0.0	0.0	**0.0**
Total	42.1	41.1	**-2.4**	29.2	-11.9	**40.8**

Before-After Analysis by Crash Severity						
	Simple Before-After Analysis			Empirical Bayes Analysis		
Crash Severity	Observed Crashes - Before Period (per year)	Observed Crashes - After Period with Treatment (per year)	Percent Change (%)	Expected Average Crashes - After Period W/O Treatment (Per Year)	Crashes Reduced (or increased) in After Period (Expected - Observed)	Percent Change using Expected Average Crashes - After Period W/O Treatment Compared with Observed Crashes - After Period with Treatment (%)
FI	3.0	9.0	**200.0**	8.8	-0.2	**2.4**
PDO	39.1	32.1	**-17.9**	20.4	-11.7	**57.4**
Total	42.1	41.1	**-2.4**	29.2	-11.9	**40.8**

Simple Before-After Analysis - Bike and Pedestrian Crashes Only			
Crash Type	Observed Crashes - Before Period (per year)	Observed Crashes - After Period with Treatment (per year)	Percent Change (%)
Bike Crashes	3.01	5.01	**66.7**
Pedestrian Crashes	1.00	1.00	**0.0**
Grand Total	4.01	6.02	**50.0**

4.2.11 Franklin Avenue (Riverside Ave. to 27th Ave. S.), Minneapolis, MN

Similar to Marshall Avenue, East Franklin Avenue is a minor arterial with a speed limit of 30 miles per hour that was reconfigured as a result of the efforts of the NTPP/BWTC project [36]. The 0.9 mile segment of the road between 22nd Street South (Cedar Avenue) and Mississippi River Bridge (MRB) (West River Parkway) as shown in Figure 4.49, was subject to a "road diet" or lane reduction that was completed in June 2011. Although the road diet was applied to the bridge, construction on the bridge began prior to the rest of the roadway in the study area in 2010 as a task in a Hennepin County intersection reconstruction project. The area surrounding Franklin Avenue is primarily residential, yet Franklin Avenue is lined with many small businesses and other commercial developments, some of which have direct access to the street via driveways. Businesses that do not have driveways on Franklin Aveenue are typically accessed via driveways located on intersecting streets. There are 10 Metro Transit bus stops along the segment which are part of a larger transit network along Franklin Avenue to both the east and west of the study area.

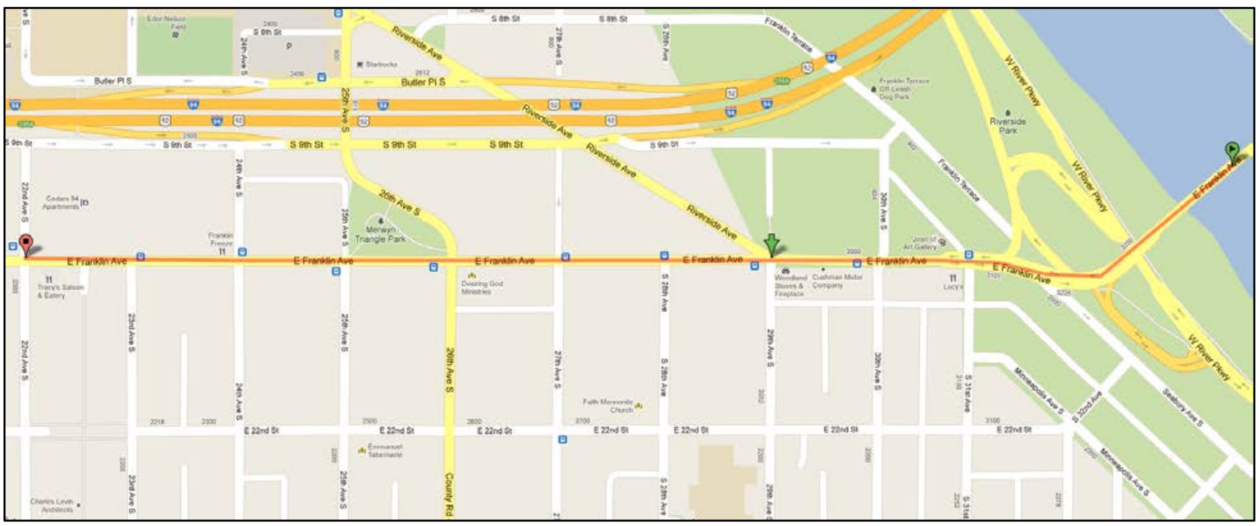

Figure 4.49: Franklin Avenue Study Area

Source: Google Maps. http://www.google.com/maps (Accessed 28 September, 2012).

<u>4.2.11.1 Conditions Before and After Reconstruction</u>

Before the "road diet," the cross-section of Franklin Avenue was 44 feet wide and composed of four travel lanes. After the lane reduction, although the overall width remained the same, the cross-section was changed to include only two through lanes and a turn lane between them at intersections. Additionally, bicycle lanes were provided on each side of the road (as seen in the cross-section displayed in Figure 4.50) and added to the bridge over the Mississippi River. Other improvements for bicyclists included bicycle boxes at the intersection of Franklin Avenue and East River Parkway and physical space/delineation provided between bicycle lanes and right turn lanes. Pedestrian sidewalks remained the same after reconstruction and the curb extensions as shown in Figure 4.50 were not added to the final design. Figures 4.51, 4.52, 4.53, and 4.54 illustrate the changes before and after reconstruction in a section of the study area near the bridge showing changes due to road diet and addition of bicycle lanes.

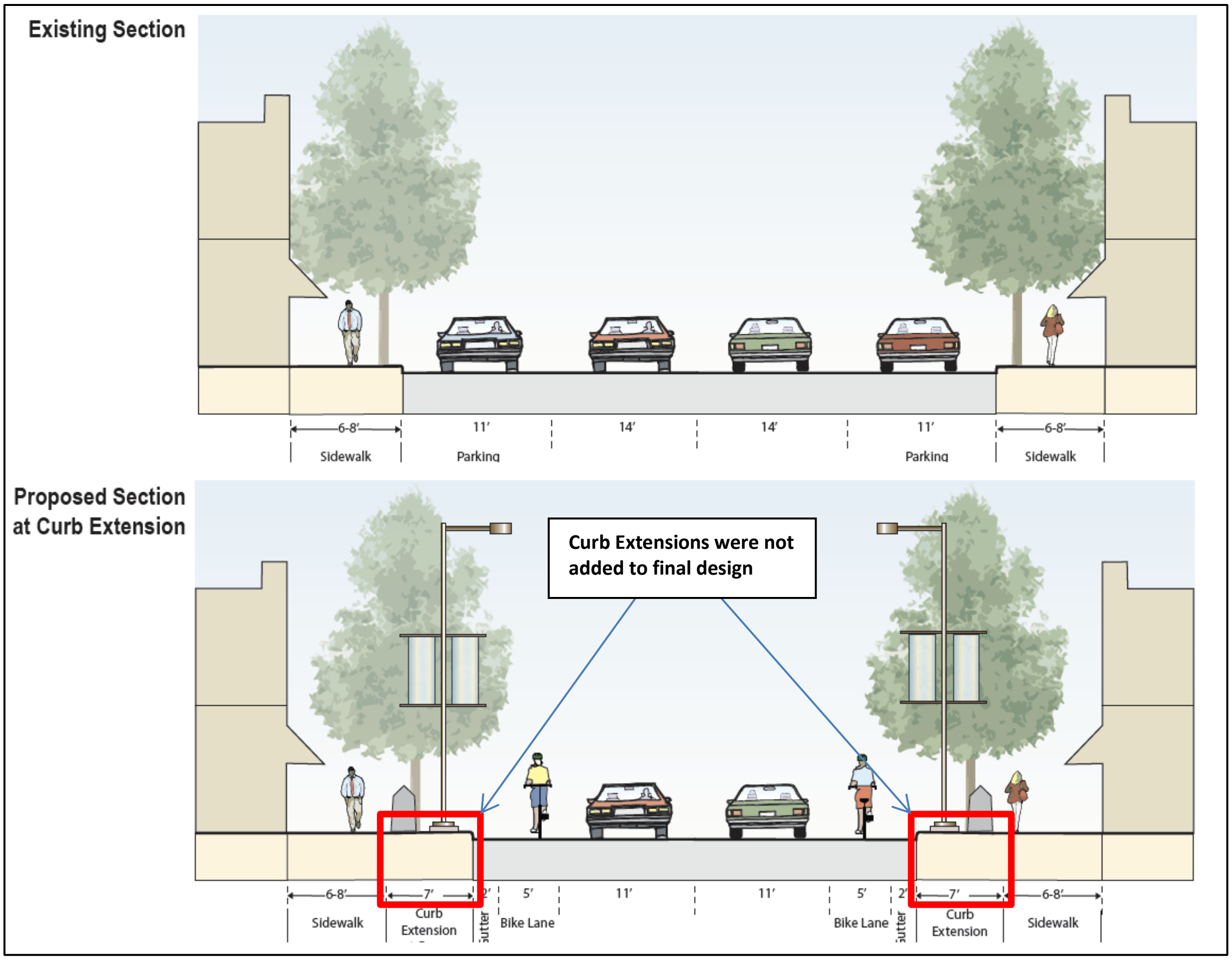

Figure 4.50: Franklin Avenue Cross-Section Before and After Reconstruction with Newly Added Bicycle Lanes

Figure 4.51: East End of Franklin Avenue Before Reconstruction Showing Four Travel Lanes

Figure 4.52: East End of Franklin Avenue After Reconstruction Showing Two Travel Lanes and Bicycle Lane

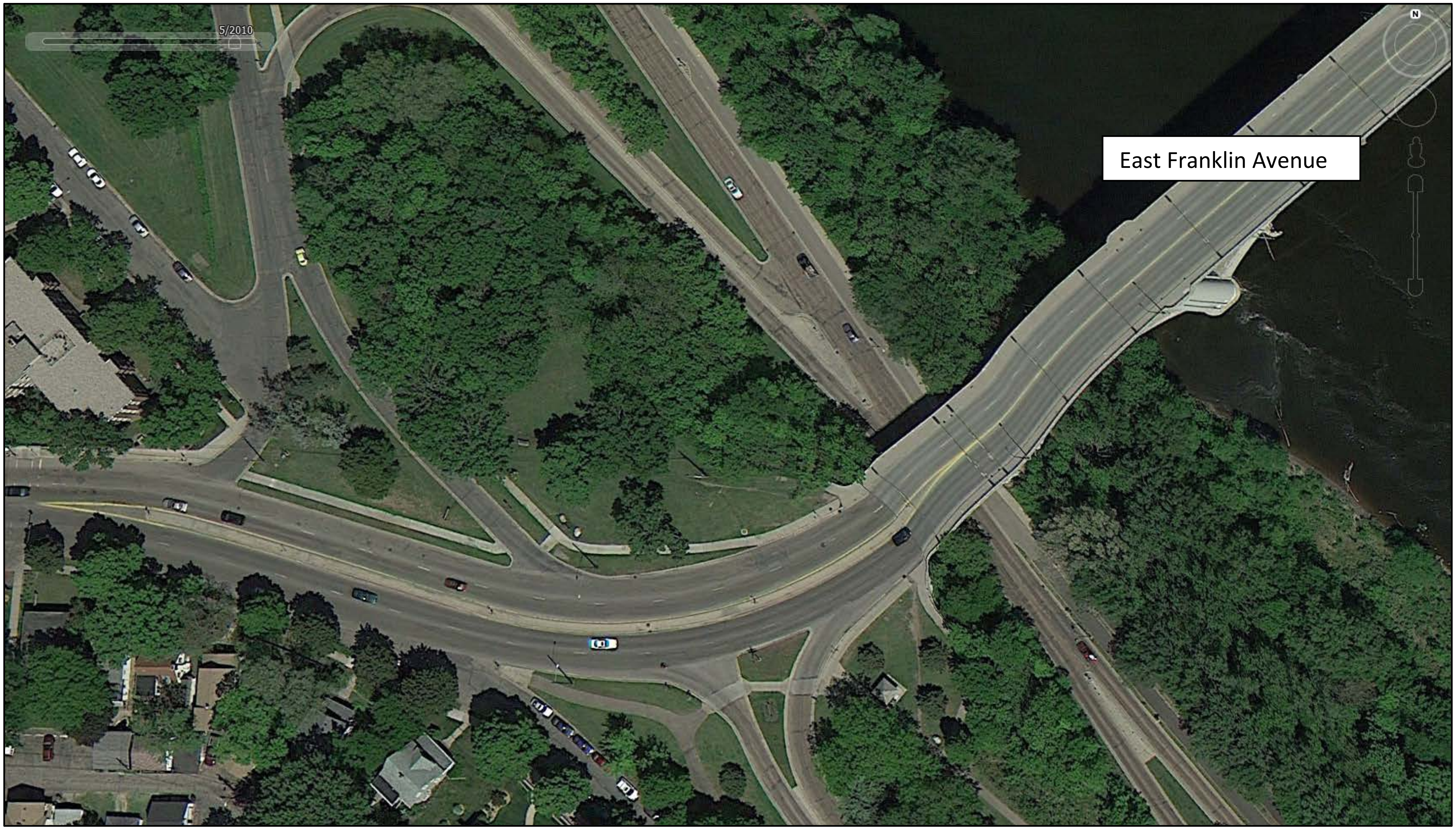

Figure 4.53: East Franklin Avenue Near Mississippi River Bridge Before Reconstruction Showing Four Travel Lanes
Source: Google Earth 6.2.2.6613. (May, 2010). East Franklin Avenue, 93°13'31.00"W, 44°57'46.30"N, Elevation 1639 ft. http://www.google.com/earth/index.html (Accessed 28 September, 2012).

Figure 4.54: East Franklin Avenue Near Mississippi River Bridge After Reconstruction Showing Two Travel Lanes

Source: Google Earth 6.2.2.6613. (April, 2012). East Franklin Avenue, 93°13'31.00"W, 44°57'46.30"N, Elevation 1639 ft. http://www.google.com/earth/index.html (Accessed 28 September, 2012).

4.2.11.2 Crash Data Analysis

Safety evaluation of reconstruction work at Franklin Avenue was conducted using 1.0 and 0.8 years of before and after crash data, respectively. Table 4.22 presents data on AADT and total number of crashes at the site in periods prior to and after the reconstruction. Detailed before-after crash analysis results using simple and EB methods is presented in Table 4.23.

Table 4.22: Crash Data for Franklin Avenue Study Area

Franklin Ave. (Cedar Ave. to Mississippi River Bridge, West River Parkway)		
	Before (2010 – 2010)	After 2011 (2012 – 10/31/2012)
	1 year	0.8 years
Segment Length	0.9 Miles	
ADT	8,700 – 12,600	9,200 – 13,300
Speed Limit	30 MPH	30 MPH
Total Crashes	39	42
FI	6	16
PDO	33	26
Rear-end	10	11
Head-on	0	0
Angle	16	13
Sideswipe, same direction	1	5
Sideswipe, opposite direction	2	0
Driveway-related	0	0
Other multiple-vehicle	4	7
Collision with animal	0	0
Collision with fixed object	4	4
Collision with other object	1	2
Other single-vehicle	1	0
Bicycle Crashes	4	6
Pedestrian Crashes	0	2

The results of simple before-after and EB analysis show mixed results with increases and decreases in certain types of crashes. Crash severity analysis also shows an increase in FI crashes and reduction in PDO crashes. However, similar to Marshall Avenue locations, it is difficult to make conclusions about specific safety impacts because the number of years of crash data available in the before and after period was less than two; therefore caution should be used in interpreting the results.

The number of bicycle crashes has increased from four to six and pedestrian crashes from 0 to 2. Although this indicates an increasing trend, once again it is difficult to ascertain any significant to these results in the absence of long term data. Overall, no significant conclusions can be drawn from the results because crash data was only available for one year in the before and after periods.

Table 4.23: Summary Results of Simple and EB Before-After Crash Analysis - Franklin Avenue

Before-After Analysis by Crash Type						
	Simple Before-After Analysis			Empirical Bayes Analysis		
Crash Type	Observed Crashes - Before Period (per year)	Observed Crashes - After Period with Treatment (per year)	Percent Change (%)	Expected Average Crashes - After Period W/O Treatment (Per Year)	Crashes Reduced (or increased) in After Period (Expected - Observed)	Percent Change using Expected Average Crashes - After Period W/O Treatment Compared with Observed Crashes - After Period with Treatment (%)
When interpreting the results, caution should be used when crashes per year are less than 0.5 or less than 2 year of crash data is available						
Multiple Vehicles						
Rear End	10.0	13.3	**32.1**	10.1	-3.2	**31.4**
Head On	0.0	0.0	**0.0**	0.0	0.0	**0.0**
Angle	16.0	15.7	**-2.4**	15.9	0.2	**-1.4**
Sideswipe - Same Direction	1.0	6.0	**500.7**	0.4	-5.6	**1470.7**
Sideswipe Opposite Direction	2.0	0.0	**-100.0**	1.0	1.0	**-100.0**
Other Multiple Vehicle	4.0	8.4	**110.2**	2.6	-5.8	**223.3**
Driveway Related	0.0	0.0	**0.0**	1.1	1.1	**-100.0**
Single Vehicle						
Animal Crash	0.0	0.0	**0.0**	0.0	0.0	**0.0**
Fixed Object Crash	4.0	4.8	**20.1**	3.6	-1.2	**34.0**
Other Object Crash	1.0	2.4	**140.3**	0.6	-1.8	**320.9**
Other Single Vehicle Crash	1.0	0.0	**-100.0**	0.6	0.6	**-100.0**
Total	39.1	50.6	**29.4**	35.8	-14.8	**41.5**

Before-After Analysis by Crash Severity						
	Simple Before-After Analysis			Empirical Bayes Analysis		
Crash Severity	Observed Crashes - Before Period (per year)	Observed Crashes - After Period with Treatment (per year)	Percent Change (%)	Expected Average Crashes - After Period W/O Treatment (Per Year)	Crashes Reduced (or increased) in After Period (Expected - Observed)	Percent Change using Expected Average Crashes - After Period W/O Treatment Compared with Observed Crashes - After Period with Treatment (%)
FI	6.0	19.3	**220.4**	11.2	-8.1	**72.3**
PDO	33.1	31.3	**-5.4**	24.6	-6.7	**27.4**
Total	39.1	50.6	**29.4**	35.8	-14.8	**41.5**

Simple Before-After Analysis - Bike and Pedestrian Crashes Only			
Crash Type	Observed Crashes - Before Period (per year)	Observed Crashes - After Period with Treatment (per year)	Percent Change (%)
Bike Crashes	4.01	7.23	**80.2**
Pedestrian Crashes	0.00	2.41	**100.0**
Grand Total	4.01	9.64	**140.3**

Chapter 5: Summary and Conclusions

The differences in the characteristics of the study sites and varying degrees of changes and improvements conducted at each specific location created difficulties in quantifying the implications of complete street improvements in an aggregate manner. Even though certain study sites had similar characteristics and improvements in terms of number of lanes, functional classification, traffic volume, etc.; differences in the type of surrounding area, roadside environment, and construction improvements made direct comparison difficult. Therefore, identifying distinct criteria (e.g., in terms of traffic volume or functional classification) to provide guidance for identifying future candidate locations for complete street improvements is not possible. Nevertheless, the set of 11 study sites did provide a diverse mix of roadways and improvements to analyze complete street implementation from different perspectives; providing a good understanding of the specific characteristics of sites and the types of changes implemented which resulted in either increased or decreased safety as part of complete street improvements. Overall, the complete street improvements implemented at the study sites did not indicate any occurrences of significant safety issues after reconstruction and in general, safety was improved. The results seem to suggest that 'flexibility' in State Aid Design Standards, in the context of complete streets, did not lead to adverse outcomes. Although quantitative analysis of traffic operations was not possible, primarily due to data limitations, anecdotal review of each study site and comments from local officials suggest that no significant operational impacts were experienced with any of the project evaluated.

Included in this chapter is a quick reference guide to the 11 study sites analyzed as part of this research. The idea is to help engineers identify study sites which match closely with future complete street candidate locations and correlate data associated with specific construction changes. Furthermore, the results provide engineers with information on specific changes which may be contrary to State Aid Design Standards but did not result in any adverse safety impacts.

It should be noted that in reviewing the results for each location, attention should be paid to the number of years of available data and the total number of crashes in specific cases. Caution should be used in analyzing results when less than two years of crash data is available or the number of crashes per year is less than 0.5. Detailed review of site characteristics and safety evaluation as described in Chapter 4 provides some anecdotal evidence on which types of improvements and locations would best serve the objectives of complete streets.

5.1 Summary Results, Conclusions, and General Guidance on Implications of Complete Street Improvements

Summary results of safety evaluation using multiple vehicle crashes, single vehicle crashes, crash severity, and bicycle and pedestrian crashes are presented in tables 5.1, 5.2, 5.3, and 5.4, respectively. Also included in the tables are site characteristics and types of improvements in order to present a qualitative review of the implications of complete street changes. Although many changes were implemented at specific sites, some of the more prevalent changes were related to lane width reduction (11 foot lanes), curb parking or parking lanes, curb extensions, bike lanes, median construction, and turning lanes.

Table 5.1: Summary Results of Simple and EB Before-After Crash Analysis of Multiple Vehicle Crashes for All Sites

					Before-After Crash % Change		Site Characteristics and Improvement Type															
Site No.	Road Name	Before Period (years)	After Period (years)	Multiple Vehicle Crash Types	Simple	EB	No. of Lanes	Traffic Volume (ADT)	Functional Classification	Divided / Undivided	Transit	Area Type	Heavy Vehicle Volume (ADT)	Speed Limit (mph)	Lane Drop (Y/N)	Lane Width After Reconstruction (ft)	Curb Extensions (Y/N)	Bike Lanes (Y/N)	Parking Eliminated (Y/N)	Raised Median Added (Y/N)	Pavement Improvements (Y/N)	Sidewalk Added / Widened (Y/N)
1	Excelsior Blvd.	2.8	2.2	Rear End	-4.0	-2.3	4	20,000	Minor Arterial	Divided	4 Stops	Residential / Commercial	Not Available	35	N	11-12[1]	Y	N	N	N	Y	Y
				Head On	0.0	0.0																
				Angle	-100.0	-100.0																
				SSS	-100.0	-100.0																
				SSOP	-100.0	-100.0																
				Other	0.0	0.0																
				Driveway	0.0	-100.0																
				Total Crashes (Multi and Single)	**-13.1**	**-16.2**																
2	Lyndale Ave.	3.4	2.3	Rear End	-54.6	-52.1	2	14,600	Minor Arterial	Undivided	1 Stop	Residential	Not Available	30	N	11-12[1]	N	N	N	Y	Y	N
				Head On	-26.8	66.1*																
				Angle	-55.4	-50.5																
				SSS	-21.2	3.1																
				SSOP	100.0	100.0																
				Other	-41.4	-16.7*																
				Driveway	-26.8	-75.5																
				Total Crashes (Multi and Single)	**-47.0**	**-42.1**																
3	West 110th St.			Rear End	N/A	N/A	4	4,350	Collector	Undivided	15 Stops	Residential	Not Available	30	Y	12	N	N	N	N	Y	N
				Head On																		
				Angle																		
				SSS																		
				SSOP																		
				Other																		
				Driveway																		
				Total Crashes (Multi and Single)																		
4	Lake St.	3.4	5.3	Rear End	2.8	4.0	4	21,500	Arterial	Undivided	10 Stops	Commercial	Not Available	30	N	11-12[1]	Y	N	N	N	Y	Y
				Head On	-16.3	59.4																
				Angle	-10.4	-9.9																
				SSS	9.1	28.2																
				SSOP	15.3	149.3																
				Other	-60.2	-59.9																
				Driveway	-76.7	-83.8																
				Total Crashes (Multi and Single)	**-17.4**	**-14.0**																

5	76th St. / CR-52	1*	0.7*	Rear End	33.3	7.4	2	5,300	Minor Arterial	Undivided	14 Stops	Residential	Not Available	30	Y	11	Y	Y	Y	N	Y	Y
				Head On	0.0	-100*																
				Angle	-11.1	104.3																
				SSS	-100.0	-100.0																
				SSOP	0.0	-100*																
				Other	0.0	-100*																
				Driveway	0.0	-100.0																
				Total Crashes (Multi and Single)	**-14.3**	**5.5**																
6	TH 14			Rear End	N/A	N/A	4	4,600	Minor Arterial	Divided	0 Stops	Rural / Commercial	345	55	N	12	N	Y	N	Y	Y	Y
				Head On																		
				Angle																		
				SSS																		
				SSOP																		
				Other																		
				Driveway																		
				Total Crashes (Multi and Single)																		
7	TH 169	3	1.2*	Rear End	8.3	5.8	4	19,700	Arterial	Divided/T WLTL	0 Stops	Residential / Commercial	2800	35	N	12-14	Y	N	N	Y	Y	Y
				Head On	0.0	0.0																
				Angle	-16.3	-15.6																
				SSS	-75.9	-71.8																
				SSOP	100.0	100.0																
				Other	381.3*	537.9*																
				Driveway	0.0	-100*																
				Total Crashes (Multi and Single)	**-17.1**	**-12.8**																
8	Hennepin Ave.	2.1	1.1*	Rear End	-47.4	N/A	4	21,900	Arterial	Undivided	4 Stops / Light Rail	CBD / Commercial	Not Available	30	N	10-11[1]	N	Y	Y	N	N	N
				Head On	100.0																	
				Angle	-62.7																	
				SSS	-44.9																	
				SSOP	-3.6																	
				Other	-72.4																	
				Driveway	-100.0																	
				Total Crashes (Multi and Single)	**-49.8**																	
8	1st Ave.	2.1	1*	Rear End	-47.9	N/A	3	23,600	Arterial	Undivided	2 Stops / Light Rail	CBD / Commercial	Not Available	30	N	10-11[1]	N	Y	N	N	N	N
				Head On	0.0																	
				Angle	-53.7																	
				SSS	-30.6																	
				SSOP	0.0																	
				Other	-100.0																	
				Driveway	0.0																	
				Total Crashes (Multi and Single)	**-54.7**																	

9	Williamson St.	3	0.9*	Rear End	-19.8	-19.4	2	21,500	Arterial	Undivided	0 Stops	Residential / Commercial	Not Available	30	N	10	Y	N	N	N	Y	Y
				Head On	0.0	0.0																
				Angle	-74.8	-70.2																
				SSS	64.1	103.7																
				SSOP	-100.0	-100*																
				Other	-100.0	-100*																
				Driveway	0.0	-100.0																
				Total Crashes (Multi and Single)	**-12.5**	**-12.2**																
10	Marshall Ave.	1*	1*	Rear End	23.5	34.4	4	19,000	Minor Arterial	Undivided	3 Stops	Residential	Not Available	35	N	10-14	N	Y	N	N	N	Y
				Head On	-50.0	103.7																
				Angle	-18.2	25.9																
				SSS	500.0	3362*																
				SSOP	0.0	0.0																
				Other	0.0	80.6																
				Driveway	-100.0	-100.0																
				Total Crashes (Multi and Single)	**-2.4**	**40.8**																
11	Franklin Ave.	1*	0.8*	Rear End	23.5	34.4	4	13,300	Minor Arterial	Undivided	2 Stops	Residential / Commercial	Not Available	30	Y	11	N	Y	Y	N	Y	N
				Head On	-50.0	103.7																
				Angle	-18.2	25.9																
				SSS	500.0	3362*																
				SSOP	0.0	0.0																
				Other	0.0	80.6																
				Driveway	-100.0	-100.0																
				Total Crashes (Multi and Single)	**-2.4**	**40.8**																

*** Indicates that available crash data is less than 2 years or either before or after number of crashes per year is less than 0.5 and greater than 0**
1 Indicates that the available numbers are approximate

Table 5.2: Summary Results of Simple and EB Before-After Crash Analysis of Single Vehicle Crashes for All Sites

					Before-After Crash % Change		Site Characteristics and Improvement Type															
Site No.	Road Name	Before Period (years)	After Period (years)	Single Vehicle Crash Types	Simple	EB	No. of Lanes	Traffic Volume (ADT)	Functional Classification	Divided / Undivided	Transit	Area Type	Heavy Vehicle Volume (ADT)	Speed Limit (mph)	Lane Drop (Y/N)	Lane Width After Reconstruction (ft)	Curb Extensions (Y/N)	Bike Lanes (Y/N)	Parking Eliminated (Y/N)	Raised Median Added (Y/N)	Pavement Improvements (Y/N)	Sidewalk Added / Widened (Y/N)
1	Excelsior Blvd.	2.8	2.2	Animal	0.0	-100*	4	20,000	Minor Arterial	Divided	4 Stops	Residential / Commercial	Not Available	35	N	11-12[1]	Y	N	N	N	Y	Y
				Fixed Object	403.8*	156.1																
				Other Object	0.0	-100.0																
				Other Single Vehicle	0.0	-100*																
				Total Crashes (Multi and Single)	**-13.1**	**-16.2**																
2	Lyndale Ave.	3.4	2.3	Animal	-51.2*	-3.5*	2	14,600	Minor Arterial	Undivided	1 Stop	Residential	Not Available	30	N	11-12[1]	N	N	N	Y	Y	N
				Fixed Object	192.8*	200.2*																
				Other Object	-85.4*	-86.0																
				Other Single Vehicle	-100*	-100*																
				Total Crashes (Multi and Single)	**-47.0**	**-42.1**																
3	West 110th St.			Animal	N/A	N/A	4	4,350	Collector	Undivided	15 Stops	Residential	Not Available	30	Y	12	N	N	N	N	Y	N
				Fixed Object																		
				Other Object																		
				Other Single Vehicle																		
				Total Crashes (Multi and Single)																		
4	Lake St.	3.4	5.3	Animal	0.0	0.0	4	21,500	Arterial	Undivided	10 Stops	Commercial	Not Available	30	N	11-12[1]	Y	N	N	N	Y	Y
				Fixed Object	-2.40	0.0																
				Other Object	35.20	50.5																
				Other Single Vehicle	100.00	100.0																
				Total Crashes (Multi and Single)	**-17.4**	**-14.0**																
5	76th St. / CR-52	1*	0.7*	Animal	0.0	-100.0	2	5,300	Minor Arterial	Undivided	14 Stops	Residential	Not Available	30	Y	11	Y	Y	Y	N	Y	Y
				Fixed Object	-33.30	-36.8																
				Other Object	0.00	-100.0																
				Other Single Vehicle	0.00	-100*																
				Total Crashes (Multi and Single)	**-14.3**	**5.5**																

6	TH 14			Animal	N/A	N/A	4	4,600	Minor Arterial	Divided	0 Stops	Rural / Commercial	345	55	N	12	N	Y	N	Y	Y	Y
				Fixed Object																		
				Other Object																		
				Other Single Vehicle																		
				Total Crashes (Multi and Single)																		
7	TH 169	3	1.2*	Animal	-100.0	-100.0	4	19,700	Arterial	Divided / TWLTL	0 Stops	Residential / Commercial	2800	35	N	12-14	Y	N	N	Y	Y	Y
				Fixed Object	-59.9	-46.4																
				Other Object	-100.0	-100.0																
				Other Single Vehicle	-100.0	-100.0																
				Total Crashes (Multi and Single)	**-17.1**	**-12.8**																
8	Hennepin Ave.	2.1	1.1*	Animal	0.0	N/A	4	21,900	Arterial	Undivided	4 Stops/ Light Rail	CBD / Commercial	Not Available	30	N	10-11[1]	N	Y	Y	N	N	N
				Fixed Object	-100.0																	
				Other Object	-35.7																	
				Other Single Vehicle	-100.0																	
				Total Crashes (Multi and Single)	**-49.8**																	
8	1st Ave.	2.1	1*	Animal	0.0	N/A	3	23,600	Arterial	Undivided	2 Stops/ Light Rail	CBD / Commercial	Not Available	30	N	10-11[1]	N	Y	N	N	N	N
				Fixed Object	4.1																	
				Other Object	0.0																	
				Other Single Vehicle	0.0																	
				Total Crashes (Multi and Single)	**-54.7**																	
9	Williamson St.	3	0.9*	Animal	0.0	0.0	2	21,500	Arterial	Undivided	0 Stops	Residential / Commercial	Not Available	30	N	10	Y	N	N	N	Y	Y
				Fixed Object	64.1	20.7																
				Other Object	-100*	-100.0																
				Other Single Vehicle	556.3*	346.0																
				Total Crashes (Multi and Single)	**-12.5**	**-12.2**																
10	Marshall Ave.	1*	1*	Animal	0.0	0.0	4	19,000	Minor Arterial	Undivided	3 Stops	Residential	Not Available	35	N	10-14	N	Y	N	N	N	Y
				Fixed Object	-50.0	2.2																
				Other Object	-100.0	-100.0																
				Other Single Vehicle	0.0	0.0																
				Total Crashes (Multi and Single)	**-2.4**	**40.8**																

11	Franklin Ave.	1*	0.8*	Animal	0.0	0.0	4	13,300	Minor Arterial	Undivided	2 Stops	Residential / Commercial	Not Available	30	Y	11	N	Y	Y	N	Y	N
				Fixed Object	20.1	34.0																
				Other Object	140.3	320.9																
				Other Single Vehicle	-100.0	-100.0																
				Total Crashes (Multi and Single)	**29.4**	**41.5**																

*** Indicates that available crash data is less than 2 years or either before or after number of crashes per year is less than 0.5 and greater than 0**

1 Indicates that the available numbers are approximate

Table 5.3: Summary Results of Simple and EB Before-After Crash Analysis of Crash Severity for All Sites

Site No.	Road Name	Before Period (years)	After Period (years)	Crash Severity	Before-After Crash % Change: Simple	Before-After Crash % Change: EB	Site Characteristics and Improvement Type: No. of Lanes	Traffic Volume (ADT)	Functional Classification	Divided / Undivided	Transit	Area Type	Heavy Vehicle Volume (ADT)	Speed Limit (mph)	Lane Drop (Y/N)	Lane Width After Reconstruction (ft)	Curb Extensions (Y/N)	Bike Lanes (Y/N)	Parking Eliminated (Y/N)	Raised Median Added (Y/N)	Pavement Improvements (Y/N)	Sidewalk Added / Widened (Y/N)
1	Excelsior Blvd.	2.8	2.2	FI	51.1	-5.7	4	20,000	Minor Arterial	Divided	4 Stops	Residential / Commercial	Not Available	35	N	11-12[1]	Y	N	N	N	Y	Y
				PDO	-47.5	-42.9																
				Total Crashes (Multi and Single)	**-13.1**	**-16.2**																
2	Lyndale Ave.	3.4	2.3	FI	-40.3	-34.4	2	14,600	Minor Arterial	Undivided	1 Stop	Residential	Not Available	30	N	11-12[1]	N	N	N	Y	Y	N
				PDO	-49.7	-45.2																
				Total Crashes (Multi and Single)	**-47.0**	**-42.1**																
3	West 110th St.			FI	N/A	N/A	4	4,350	Collector	Undivided	15 Stops	Residential	Not Available	30	Y	12	N	N	N	N	Y	N
				PDO																		
				Total Crashes (Multi and Single)																		
4	Lake St.	3.4	5.3	FI	-26.2	-26.1	4	21,500	Arterial	Undivided	10 Stops	Commercial	Not Available	30	N	11-12[1]	Y	N	N	N	Y	Y
				PDO	-13.7	-8.6																
				Total Crashes (Multi and Single)	**-17.4**	**-14.0**																
5	76th St. / CR-52	1*	0.7*	FI	33.3	107.5	2	5,300	Minor Arterial	Undivided	14 Stops	Residential	Not Available	30	Y	11	Y	Y	Y	N	Y	Y
				PDO	-50.0	-46.8																
				Total Crashes (Multi and Single)	**-14.3**	**5.5**																
6	TH 14			FI	N/A	N/A	4	4,600	Minor Arterial	Divided	0 Stops	Rural / Commercial	345	55	N	12	N	Y	N	Y	Y	Y
				PDO																		
				Total Crashes (Multi and Single)																		
7	TH 169	3	1.2*	FI	-33.2	-46.4	4	19,700	Arterial	Divided / TWLTL	0 Stops	Residential / Commercial	2800	35	N	12-14	Y	N	N	Y	Y	Y
				PDO	-13.1	-0.8																
				Total Crashes (Multi and Single)	**-17.1**	**-12.8**																
8	Hennepin Ave.	2.1	1.1*	FI	-24.2	N/A	4	21,900	Arterial	Undivided	4 Stops / Light Rail	CBD / Commercial	Not Available	30	N	10-11[1]	N	Y	Y	N	N	N
				PDO	-59.3																	
				Total Crashes (Multi and Single)	**-49.8**																	
8	1st Ave.	2.1	1*	FI	56.2	N/A	3	23,600	Arterial	Undivided	2 Stops / Light Rail	CBD / Commercial	Not Available	30	N	10-11[1]	N	Y	N	N	N	N
				PDO	-78.1																	
				Total Crashes (Multi and Single)	**-54.7**																	

9	Williamson St.	3	0.9*	FI	-42.9	-44.1	2	21,500	Arterial	Undivided	0 Stops	Residential / Commercial	Not Available	30	N	10	Y	N	N	N	Y	Y
				PDO	1.0	2.4																
				Total Crashes (Multi and Single)	**-12.5**	**-12.2**																
10	Marshall Ave.	1*	1*	FI	200.0	2.4	4	19,000	Minor Arterial	Undivided	3 Stops	Residential	Not Available	35	N	10-14	N	Y	N	N	N	Y
				PDO	-17.9	57.4																
				Total Crashes (Multi and Single)	**-2.4**	**40.8**																
11	Franklin Ave.	1*	0.8*	FI	220.4	72.3	4	13,300	Minor Arterial	Undivided	2 Stops	Residential / Commercial	Not Available	30	Y	11	N	Y	Y	N	Y	N
				PDO	-5.4	27.4																
				Total Crashes (Multi and Single)	**29.4**	**41.5**																

*** Indicates that available crash data is less than 2 years or either before or after number of crashes per year is less than 0.5 and greater than 0**

1 Indicates that the available numbers are approximate

Table 5.4: Summary Results of Simple Before-After Crash Analysis of Bicycle and Pedestrian Crashes for All Sites

Site No.	Road Name	Before Period (years)	After Period (years)	Crash Type	Simple Before-After Crash % Change	Site Characteristics and Improvement Type: No. of Lanes	Traffic Volume (ADT)	Functional Classification	Divided / Undivided	Transit	Area Type	Heavy Vehicle Volume (ADT)	Speed Limit (mph)	Lane Drop (Y/N)	Lane Width After Reconstruction (ft)	Curb Extensions (Y/N)	Bike Lanes (Y/N)	Parking Eliminated (Y/N)	Raised Median Added (Y/N)	Pavement Improvements (Y/N)	Sidewalk Added / Widened (Y/N)
1	Excelsior Blvd.	2.8	2.2	Bicycle	25.9*	4	20,000	Minor Arterial	Divided	4 Stops	Residential / Commercial	Not Available	35	N	11-12[1]	Y	N	N	N	Y	Y
				Pedestrian	100.0																
				Total Crashes	**277.8**																
2	Lyndale Ave.	3.4	2.3	Bicycle	-26.8*	2	14,600	Minor Arterial	Undivided	1 Stop	Residential	Not Available	30	N	11-12[1]	N	N	N	Y	Y	N
				Pedestrian	-63.4*																
				Total Crashes	**-51.2**																
3	West 110th St.			Bicycle	N/A	4	4,350	Collector	Undivided	15 Stops	Residential	Not Available	30	Y	12	N	N	N	N	Y	N
				Pedestrian																	
				Total Crashes																	
4	Lake St.	3.4	5.3	Bicycle	196.1	4	21,500	Arterial	Undivided	10 Stops	Commercial	Not Available	30	N	11-12[1]	Y	N	N	N	Y	Y
				Pedestrian	70.7																
				Total Crashes	**114.4**																
5	76th St. / CR-52	1*	0.7*	Bicycle	N/A	2	5,300	Minor Arterial	Undivided	14 Stops	Residential	Not Available	30	Y	11	Y	Y	Y	N	Y	Y
				Pedestrian																	
				Total Crashes																	
6	TH 14			Bicycle	N/A	4	4,600	Minor Arterial	Divided	0 Stops	Rural / Commercial	345	55	N	12	N	Y	N	Y	Y	Y
				Pedestrian																	
				Total Crashes																	
7	TH 169	3	1.2*	Bicycle	-100*	4	19,700	Arterial	Divided / TWLTL	0 Stops	Residential / Commercial	2800	35	N	14-Dec	Y	N	N	Y	Y	Y
				Pedestrian	0.0																
				Total Crashes	**-100.0**																
8	Hennepin Ave.	2.1	1.1*	Bicycle	-74.8	4	21,900	Arterial	Undivided	4 Stops / Light Rail	CBD / Commercial	Not Available	30	N	10-11[1]	N	Y	Y	N	N	N
				Pedestrian	-64.9																
				Total Crashes	**-71.6**																
8	1st Ave.	2.1	1*	Bicycle	0.0	3	23,600	Arterial	Undivided	2 Stops / Light Rail	CBD / Commercial	Not Available	30	N	10-11[1]	N	Y	N	N	N	N
				Pedestrian	-100.0																
				Total Crashes	**-100.0**																
9	Williamson St.	3	0.9*	Bicycle	-100.0	2	21,500	Arterial	Undivided	0 Stops	Residential / Commercial	Not Available	30	N	10	Y	N	N	N	Y	Y
				Pedestrian	0.0																
				Total Crashes	**-100.0**																

10	Marshall Ave.	1*	1*	Bicycle	66.7	4	19,000	Minor Arterial	Undivided	3 Stops	Residential	Not Available	35	N	10-14	N	Y	N	N	N	Y
				Pedestrian	0.0																
				Total Crashes	**50.0**																
11	Franklin Ave.	1*	0.8*	Bicycle	80.2	4	13,300	Minor Arterial	Undivided	2 Stops	Residential / Commercial	Not Available	30	Y	11	N	Y	Y	N	Y	N
				Pedestrian	100.0																
				Total Crashes	**140.3**																

*** Indicates that available crash data is less than 2 years or either before or after number of crashes per year is less than 0.5 and greater than 0**
1 Indicates that the available numbers are approximate

The summary tables show the percent change in crashes before and after the roadway changes were implemented. Note that in the case of simple before-after crash data analysis, the percent change refers to the difference in crashes in the periods before and after reconstruction. In the case of EB before-after crash data analysis, the percent change refers to the difference in expected and observed crashes in the after period, i.e., expected crashes are an estimate of safety in the absence of any complete street improvements and reconstruction; and observed crashes are the actual crashes experienced after reconstruction. In other words, EB results show crashes with and without changes implemented at each site.

In view of the information presented in tables 5.1, 5.2, 5.3, and 5.4, and considering observed and documented information pertaining to the 11 study sites, several findings can be noted:

1. Complete street changes including lane width reduction or lane drop in some cases (i.e., low volume roads) did not have any adverse safety impacts.
2. Low volume collector roadways exhibited little impact of the cross-section changes.
3. Four lane roads with moderate/high traffic volumes (Excelsior Blvd. and Lake Street), commercial/mixed land use conditions, and no exclusive bicycle lanes may warrant additional scrutiny when considering complete street improvements especially in cases of high volumes of pedestrian and bicycle traffic.
4. No adverse safety impacts were observed in the use of 11 foot lane widths. No operational impacts were reported.
5. Literature suggests that 10-foot lanes provide no significant operational or safety impacts in suburban and urban arterials. No findings or observations in this research dispute these claims.
6. Safety was improved at certain locations after the construction of a median which is consistent with national research.
7. Driveway related crashes were reduced at most locations.
8. Safety considerations should be given to expected increases in bicycle and pedestrian traffic after complete street improvements.
9. Variation in cross-sectional dimensions produced relatively consistent results, suggesting that variability in selected design standards did not inhibit or impact other roadway elements.

As mentioned, differences in the characteristics of the study sites and varying degrees of changes and improvements conducted at each site prevented an aggregate quantification of the implications of complete street improvements across all sites, and specific recommendations for changes in design standards. Nevertheless, complete street improvements implemented at each study site did not indicate any significant impact on safety or operations after reconstruction. Overall, the analysis of complete street designs implemented at the 11 study sites suggest that changes made to these study sites did not result in adverse impacts. Therefore, providing flexibility and modification to the State Aid Design Standards in the context of complete streets and conditions specified in this research appears to be a reasonable consideration.

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Appendix A: Detailed Calculation Sheets for Empirical Bayes Analysis

Worksheet 1A -- General Information and Input Data for Urban and Suburban Roadway Segments			
General Information		**Location Information**	
Analyst	TOPS Lab	Roadway	Excelsior Blvd.
Agency or Company	TOPS	Roadway Section	Quentin Avenue and Monetery Dr.
Date Performed	01/06/13	Jurisdiction	Minneapolis, MN (Hennepin County)
		Analysis Year	

Input Data		**Base Conditions**	**Site Conditions**
Roadway type (2U, 3T, 4U, 4D, ST)		--	4D
Length of segment, L (mi)		--	0.35
AADT (veh/day)	$AADT_{MAX}$= 66,000 (veh/day)	--	20,000
Type of on-street parking (none/parallel/angle)		None	Parallel (Comm/Ind)
Proportion of curb length with on-street parking		--	0.66
Median width (ft) - for divided only		15	Not Present
Lighting (present / not present)		Not Present	Present
Auto speed enforcement (present / not present)		Not Present	Not Present
Major commercial driveways (number)		--	6
Minor commercial driveways (number)		--	6
Major industrial / institutional driveways (number)		--	0
Minor industrial / institutional driveways (number)		--	0
Major residential driveways (number)		--	0
Minor residential driveways (number)		--	0
Other driveways (number)		--	3
Speed Category		--	Posted Speed Greater than 30 mph
Roadside fixed object density (fixed objects / mi)		0	500
Offset to roadside fixed objects (ft) [If greater than 30 or Not Present, input 30]		30	4
Calibration Factor, Cr		1.00	1.00

Worksheet 1B -- Crash Modification Factors for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
CMF for On-Street Parking	CMF for Roadside Fixed Objects	CMF for Median Width	CMF for Lighting	CMF for Automated Speed Enforcement	Combined CMF
CMF 1r	*CMF 2r*	*CMF 3r*	*CMF 4r*	*CMF 5r*	*CMF comb*
from Equation 12-32	from Equation 12-33	from Table 12-22	from Equation 12-34	from Section 12.7.1	(1)*(2)*(3)*(4)*(5)
1.47	3.70	1.00	0.91	1.00	4.97

Worksheet 1C -- Multiple-Vehicle Nondriveway Collisions by Severity Level for Urban and Suburban Roadway Segments									
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)
Crash Severity Level	**SPF Coefficients**		**Overdispersion Parameter, k**	**Initial N_{brmv}**	**Proportion of Total Crashes**	**Adjusted N_{brmv}**	**Combined CMFs**	**Calibration Factor, Cr**	**Predicted N_{brmv}**
	from Table 12-3		from Table 12-3	from Equation 12-10		$(4)_{TOTAL}$*(5)	(6) from Worksheet 1B		(6)*(7)*(8)
	a	b							
Total	-12.34	1.36	1.32	1.082	1.000	1.082	4.97	1.00	5.377
Fatal and Injury (FI)	-12.76	1.28	1.31	0.322	$(4)_{FI}/((4)_{FI}+(4)_{PDO})$ 0.281	0.304	4.97	1.00	1.510
Property Damage Only (PDO)	-12.81	1.38	1.34	0.824	$(5)_{TOTAL}-(5)_{FI}$ 0.719	0.778	4.97	1.00	3.867

Worksheet 1D -- Multiple-Vehicle Nondriveway Collisions by Collision Type for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
Collision Type	**Proportion of Collision Type$_{(FI)}$**	**Predicted N $_{brmv\ (FI)}$ (crashes/year)**	**Proportion of Collision Type $_{(PDO)}$**	**Predicted N $_{brmv\ (PDO)}$ (crashes/year)**	**Predicted N $_{brmv\ (TOTAL)}$ (crashes/year)**
	from Table 12-4	$(9)_{FI}$ from Worksheet 1C	from Table 12-4	$(9)_{PDO}$ from Worksheet 1C	$(9)_{TOTAL}$ from Worksheet 1C
Total	1.000	1.510	1.000	3.867	5.377
		$(2)*(3)_{FI}$		$(4)*(5)_{PDO}$	(3)+(5)
Rear-end collision	0.800	1.208	0.739	2.858	4.067
Head-on collision	0.000	0.000	0.000	0.000	0.000
Angle collision	0.200	0.302	0.087	0.336	0.638
Sideswipe, same direction	0.000	0.000	0.087	0.336	0.336
Sideswipe, opposite direction	0.000	0.000	0.087	0.336	0.336
Other multiple-vehicle collision	0.000	0.000	0.000	0.000	0.000

Worksheet 1E -- Single-Vehicle Collisions by Severity Level for Urban and Suburban Roadway Segments									
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)
Crash Severity Level	**SPF Coefficients**		**Overdispersion Parameter, k**	**Initial N_{brsv}**	**Proportion of Total Crashes**	**Adjusted N_{brsv}**	**Combined CMFs**	**Calibration Factor, Cr**	**Predicted N_{brsv}**
	from Table 12-5		from Table 12-5	from Equation 12-13		$(4)_{TOTAL}*(5)$	(6) from Worksheet 1B		(6)*(7)*(8)
	a	b							
Total	-5.05	0.47	0.86	0.236	1.000	0.236	4.97	1.00	1.171
Fatal and Injury (FI)	-8.71	0.66	0.28	0.040	$(4)_{FI}/((4)_{FI}+(4)_{PDO})$ 0.169	0.040	4.97	1.00	0.198
Property Damage Only (PDO)	-5.04	0.45	1.06	0.195	$(5)_{TOTAL}-(5)_{FI}$ 0.831	0.196	4.97	1.00	0.973

Worksheet 1F -- Single-Vehicle Collisions by Collision Type for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
Collision Type	**Proportion of Collision Type$_{(FI)}$**	**Predicted N $_{brsv\ (FI)}$ (crashes/year)**	**Proportion of Collision Type $_{(PDO)}$**	**Predicted N $_{brsv\ (PDO)}$ (crashes/year)**	**Predicted N $_{brsv\ (TOTAL)}$ (crashes/year)**
	from Table 12-6	$(9)_{FI}$ from Worksheet 1E	from Table 12-6	$(9)_{PDO}$ from Worksheet 1E	$(9)_{TOTAL}$ from Worksheet 1E
Total	1.000	0.198	1.000	0.973	1.171
		$(2)*(3)_{FI}$		$(4)*(5)_{PDO}$	(3)+(5)
Collision with animal	0.001	0.000	0.063	0.061	0.061
Collision with fixed object	0.500	0.099	0.813	0.791	0.890
Collision with other object	0.028	0.006	0.016	0.016	0.021
Other single-vehicle collision	0.471	0.093	0.108	0.105	0.199

Worksheet 1G -- Multiple-Vehicle Driveway-Related Collisions by Driveway Type for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
Driveway Type	Number of driveways, n_j	Crashes per driveway per year, N_j	Coefficient for traffic adjustment, t	Initial N_{brdwy}	Overdispersion parameter, k
		from Table 12-7	from Table 12-7	Equation 12-16 $n_j * N_j * (AADT/15,000)^t$	from Table 12-7
Major commercial	6	0.033	1.106	0.272	--
Minor commercial	6	0.011	1.106	0.091	
Major industrial/institutional	0	0.036	1.106	0.000	
Minor industrial/institutional	0	0.005	1.106	0.000	
Major residential	0	0.018	1.106	0.000	
Minor residential	0	0.003	1.106	0.000	
Other	3	0.005	1.106	0.021	
Total	--	--	--	0.384	1.39

Worksheet 1H -- Multiple-Vehicle Driveway-Related Collisions by Severity Level for Urban and Suburban Roadway Segments						
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Crash Severity Level	Initial N_{brdwy}	Proportion of total crashes (f_{dwy})	Adjusted N_{brdwy}	Combined CMFs	Calibration factor, C_r	Predicted N_{brdwy}
	$(5)_{TOTAL}$ from Worksheet 1G	from Table 12-7	$(2)_{TOTAL}$ * (3)	(6) from Worksheet 1B		(4)*(5)*(6)
Total	0.384	1.000	0.384	4.97	1.00	1.906
Fatal and injury (FI)	--	0.284	0.109	4.97	1.00	0.541
Property damage only (PDO)	--	0.716	0.275	4.97	1.00	1.365

Worksheet 1I -- Vehicle-Pedestrian Collisions for Urban and Suburban Roadway Segments							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Crash Severity Level	Predicted N_{brmv}	Predicted N_{brsv}	Predicted N_{brdwy}	Predicted N_{br}	f_{pedr}	Calibration factor, C_r	Predicted N_{pedr}
	(9) from Worksheet 1C	(9) from Worksheet 1E	(7) from Worksheet 1H	(2)+(3)+(4)	from Table 12-8		(5)*(6)*(7)
Total	5.377	1.171	1.906	8.455	0.019	1.00	0.161
Fatal and injury (FI)	--	--	--	--	--	1.00	0.161

Worksheet 1J -- Vehicle-Bicycle Collisions for Urban and Suburban Roadway Segments							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Crash Severity Level	Predicted N_{brmv}	Predicted N_{brsv}	Predicted N_{brdwy}	Predicted N_{br}	f_{biker}	Calibration factor, C_r	Predicted N_{biker}
	(9) from Worksheet 1C	(9) from Worksheet 1E	(7) from Worksheet 1H	(2)+(3)+(4)	from Table 12-9		(5)*(6)*(7)
Total	5.377	1.171	1.906	8.455	0.005	1.00	0.042
Fatal and injury (FI)	--	--	--	--	--	1.00	0.042

Worksheet 1K -- Crash Severity Distribution for Urban and Suburban Roadway Segments			
(1)	(2)	(3)	(4)
Collision type	**Fatal and injury (FI)**	**Property damage only (PDO)**	**Total**
	(3) from Worksheet 1D and 1F; (7) from Worksheet 1H; and (8) from Worksheet 1I and 1J	(5) from Worksheet 1D and 1F; and (7) from Worksheet 1H	(6) from Worksheet 1D and 1F; (7) from Worksheet 1H; and (8) from Worksheet 1I and 1J
MULTIPLE-VEHICLE			
Rear-end collisions (from Worksheet 1D)	1.208	2.858	4.067
Head-on collisions (from Worksheet 1D)	0.000	0.000	0.000
Angle collisions (from Worksheet 1D)	0.302	0.336	0.638
Sideswipe, same direction (from Worksheet 1D)	0.000	0.336	0.336
Sideswipe, opposite direction (from Worksheet 1D)	0.000	0.336	0.336
Driveway-related collisions (from Worksheet 1H)	0.541	1.365	1.906
Other multiple-vehicle collision (from Worksheet 1D)	0.000	0.000	0.000
Subtotal	2.051	5.232	7.283
SINGLE-VEHICLE			
Collision with animal (from Worksheet 1F)	0.000	0.061	0.061
Collision with fixed object (from Worksheet 1F)	0.099	0.791	0.890
Collision with other object (from Worksheet 1F)	0.006	0.016	0.021
Other single-vehicle collision (from Worksheet 1F)	0.093	0.105	0.199
Collision with pedestrian (from Worksheet 1I)	0.161	0.000	0.161
Collision with bicycle (from Worksheet 1J)	0.042	0.000	0.042
Subtotal	0.401	0.973	1.374
Total	2.453	6.205	8.657

Worksheet 1L -- Summary Results for Urban and Suburban Roadway Segments			
(1)	(2)	(3)	(4)
Crash Severity Level	**Predicted average crash frequency, $N_{predicted\ rs}$ (crashes/year)**	**Roadway segment length, L (mi)**	**Crash rate (crashes/mi/year)**
	(Total) from Worksheet 1K		(2) / (3)
Total	8.7	0.35	24.7
Fatal and injury (FI)	2.5	0.35	7.0
Property damage only (PDO)	6.2	0.35	17.7

Worksheet 3A -- Predicted Crashes by Severity and Site Type and Observed Crashes Using the Site-Specific EB Method for Urban and Suburban Arterials								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
Collision type / Site type	Predicted average crash frequency (crashes/year)			Observed crashes, $N_{observed}$ (crashes/year)	Overdispersion Parameter, k	Weighted adjustment, w	Expected average crash frequency, $N_{expected}$	
	$N_{predicted}$ (TOTAL)	$N_{predicted}$ (FI)	$N_{predicted}$ (PDO)			Equation A-5 from Part C Appendix	Equation A-4 from Part C Appendix	
ROADWAY SEGMENTS								
Multiple-vehicle nondriveway								
Segment 1	5.377	1.510	3.867	9.88	1.320	0.123	9.327	
Segment 2	0.000	0.000	0.000		0.840	1.000	0.000	
Segment 3						1.000	0.000	
Segment 4						1.000	0.000	
Single-vehicle								
Segment 1	1.171	0.198	0.973	0.35	0.860	0.498	0.761	
Segment 2	0.003	0.003	0.000		0.810	0.997	0.003	
Segment 3						1.000	0.000	
Segment 4						1.000	0.000	
Multiple-vehicle driveway-related								
Segment 1	1.906	0.541	1.365	0.00	1.390	0.274	0.522	
Segment 2	0.000	0.000	0.000		0.810	1.000	0.000	
Segment 3						1.000	0.000	
Segment 4						1.000	0.000	
INTERSECTIONS								
Multiple-vehicle								
Intersection 1	0.000	0.000	0.000		0.800	1.000	0.000	
Intersection 2	0.000	0.000	0.000		0.390	1.000	0.000	
Intersection 3						1.000	0.000	
Intersection 4						1.000	0.000	
Single-vehicle								
Intersection 1	0.001	0.000	0.000		1.140	0.999	0.001	
Intersection 2	0.000	0.000	0.000		0.360	1.000	0.000	
Intersection 3						1.000	0.000	
Intersection 4						1.000	0.000	
COMBINED (sum of column)	8.459	2.253	6.206	10	--	--	10.615	per year

Worksheet 3B -- Predicted Pedestrian and Bicycle Crashes for Urban and Suburban Arterials

(1) Site Type	(2) N_{ped}	(3) N_{bike}	
ROADWAY SEGMENTS			
Segment 1	0.161	0.042	
Segment 2	0.000	0.000	
Segment 3			
Segment 4			
INTERSECTIONS			
Intersection 1	0.000	0.000	
Intersection 2	0.013	0.000	
Intersection 3			
Intersection 4			
COMBINED (sum of column)	0.173	0.042	per year

Worksheet 3C -- Site-Specific EB Method Summary Results for Urban and Suburban Arterials

(1)	(2)	(3)	(4)	(5)	(6)
Crash severity level	**$N_{predicted}$**	**N_{ped}**	**N_{bike}**	$N_{expected (VEHICLE)}$	$N_{expected}$
Total	$(2)_{COMB}$ from Worksheet 3A	$(2)_{COMB}$ from Worksheet 3B	$(3)_{COMB}$ from Worksheet 3B	$(8)_{COMB}$ Worksheet 3A	(3)+(4)+(5)
	8.5	0.2	0.0	10.6	10.8
Fatal and injury (FI)	$(3)_{COMB}$ from Worksheet 3A	$(2)_{COMB}$ from Worksheet 3B	$(3)_{COMB}$ from Worksheet 3B	$(5)_{TOTAL}$ * $(2)_{FI}$ / $(2)_{TOTAL}$	(3)+(4)+(5)
	2.3	0.2	0.0	2.8	3.0
Property damage only (PDO)	$(4)_{COMB}$ from Worksheet 3A	--	--	$(5)_{TOTAL}$ * $(2)_{PDO}$ / $(2)_{TOTAL}$	(3)+(4)+(5)
	6.2	0.0	0.0	7.8	7.8

Worksheet 3A -- Predicted Crashes by Severity and Crash Type and Observed Crashes Using the Site-Specific EB Method for Urban and Suburban Arterials

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(8)
Collision type / Site type	**Predicted average crash frequency (crashes/year)**			**Observed crashes,** $N_{observed}$ (crashes/year)	**Overdispersion Parameter, k**	**Weighted adjustment, w**	**Expected average crash frequency, $N_{expected}$**	**Expected average crash frequency, Adjusted**
	$N_{predicted}$ (TOTAL)	$N_{predicted}$ (FI)	$N_{predicted}$ (PDO)			Equation A-5 from Part C Appendix	Equation A-4 from Part C Appendix	
MULTIPLE VEHICLES								
Rear End	4.07	1.21	2.86	7.41	1.32	0.157	6.887	7.28
Head On	0.00	0.00	0.00	0.00	1.32	1.000	0.000	0.00
Angle	0.64	0.30	0.34	1.06	1.32	0.543	0.831	0.88
Sideswipe - Same Direction	0.34	0.00	0.34	0.71	1.32	0.693	0.450	0.48
Sideswipe - Opposite Direction	0.34	0.00	0.34	0.71	1.32	0.693	0.450	0.48
Driveway-related	1.91	0.54	1.36	0.00	1.39	0.274	0.522	0.55
Other multiple-vehicle	0.00	0.00	0.00	0.00	1.32	1.000	0.000	0.00
SINGLE VEHICLES								
Collision with animal	0.06	0.00	0.06	0.00	0.86	0.950	0.058	0.06
Collision with fixed object	0.89	0.10	0.79	0.35	0.86	0.566	0.657	0.69
Collision with other object	0.02	0.01	0.02	0.00	0.86	0.982	0.021	0.02
Other single-vehicle collision	0.20	0.09	0.11	0.00	0.86	0.854	0.170	0.18
Total	8.45	2.25	6.20				10.046	10.61

Worksheet 1A -- General Information and Input Data for Urban and Suburban Roadway Segments			
General Information		**Location Information**	
Analyst	TOPS Lab	Roadway	Lyndale Avenue
Agency or Company	TOPS	Roadway Section	West 44th St. to West 34th St.
Date Performed	01/06/13	Jurisdiction	Minneapolis, MN (Hennepin County)
		Analysis Year	

Input Data		**Base Conditions**	**Site Conditions**
Roadway type (2U, 3T, 4U, 4D, ST)		--	2U
Length of segment, L (mi)		--	1.3
AADT (veh/day)	$AADT_{MAX}$ = 32,600 (veh/day)	--	14,000
Type of on-street parking (none/parallel/angle)		None	Parallel (Residential)
Proportion of curb length with on-street parking		--	0.66
Median width (ft) - for divided only		15	Not Present
Lighting (present / not present)		Not Present	Not Present
Auto speed enforcement (present / not present)		Not Present	Not Present
Major commercial driveways (number)		--	4
Minor commercial driveways (number)		--	8
Major industrial / institutional driveways (number)		--	0
Minor industrial / institutional driveways (number)		--	0
Major residential driveways (number)		--	2
Minor residential driveways (number)		--	58
Other driveways (number)		--	0
Speed Category		--	Posted Speed 30 mph or Lower
Roadside fixed object density (fixed objects / mi)		0	130
Offset to roadside fixed objects (ft) [If greater than 30 or Not Present, input 30]		30	9
Calibration Factor, Cr		1.00	1.00

Worksheet 1B -- Crash Modification Factors for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
CMF for On-Street Parking	CMF for Roadside Fixed Objects	CMF for Median Width	CMF for Lighting	CMF for Automated Speed Enforcement	Combined CMF
CMF 1r	*CMF 2r*	*CMF 3r*	*CMF 4r*	*CMF 5r*	*CMF comb*
from Equation 12-32	from Equation 12-33	from Table 12-22	from Equation 12-34	from Section 12.7.1	(1)*(2)*(3)*(4)*(5)
1.31	1.65	1.00	1.00	1.00	2.16

Worksheet 1C -- Multiple-Vehicle Nondriveway Collisions by Severity Level for Urban and Suburban Roadway Segments									
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)
Crash Severity Level	**SPF Coefficients**		**Overdispersion Parameter, k**	**Initial N_{brmv}**	**Proportion of Total Crashes**	**Adjusted N_{brmv}**	**Combined CMFs**	**Calibration Factor, Cr**	**Predicted N_{brmv}**
	from Table 12-3		from Table 12-3	from Equation 12-10		$(4)_{TOTAL}$*(5)	(6) from Worksheet 1B		(6)*(7)*(8)
	a	b							
Total	-15.22	1.68	0.84	2.948	1.000	2.948	2.16	1.00	6.359
Fatal and Injury (FI)	-16.22	1.66	0.65	0.896	$(4)_{FI}/((4)_{FI}+(4)_{PDO})$ 0.292	0.860	2.16	1.00	1.856
Property Damage Only (PDO)	-15.62	1.69	0.87	2.174	$(5)_{TOTAL}-(5)_{FI}$ 0.708	2.087	2.16	1.00	4.503

Worksheet 1D -- Multiple-Vehicle Nondriveway Collisions by Collision Type for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
Collision Type	**Proportion of Collision Type(FI)**	**Predicted N brmv (FI) (crashes/year)**	**Proportion of Collision Type (PDO)**	**Predicted N brmv (PDO) (crashes/year)**	**Predicted N brmv (TOTAL) (crashes/year)**
	from Table 12-4	(9)FI from Worksheet 1C	from Table 12-4	(9)PDO from Worksheet 1C	(9)TOTAL from Worksheet 1C
Total	1.000	1.856	1.000	4.503	6.359
		(2)*(3)FI		(4)*(5)PDO	(3)+(5)
Rear-end collision	0.500	0.928	0.333	1.501	2.429
Head-on collision	0.000	0.000	0.035	0.158	0.158
Angle collision	0.350	0.650	0.281	1.264	1.914
Sideswipe, same direction	0.100	0.186	0.193	0.869	1.055
Sideswipe, opposite direction	0.000	0.000	0.000	0.000	0.000
Other multiple-vehicle collision	0.050	0.093	0.158	0.711	0.804

Worksheet 1E -- Single-Vehicle Collisions by Severity Level for Urban and Suburban Roadway Segments									
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)
Crash Severity Level	**SPF Coefficients**		**Overdispersion Parameter, k**	**Initial N_{brsv}**	**Proportion of Total Crashes**	**Adjusted N_{brsv}**	**Combined CMFs**	**Calibration Factor, Cr**	**Predicted N_{brsv}**
	from Table 12-5		from Table 12-5	from Equation 12-13		(4)TOTAL*(5)	(6) from Worksheet 1B		(6)*(7)*(8)
	a	b							
Total	-5.47	0.56	0.81	1.149	1.000	1.149	2.16	1.00	2.478
Fatal and Injury (FI)	-3.96	0.23	0.50	0.223	(4)FI/((4)FI+(4)PDO) 0.204	0.234	2.16	1.00	0.504
Property Damage Only (PDO)	-6.51	0.64	0.87	0.871	(5)TOTAL-(5)FI 0.796	0.915	2.16	1.00	1.974

Worksheet 1F -- Single-Vehicle Collisions by Collision Type for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
Collision Type	**Proportion of Collision Type(FI)**	**Predicted N brsv (FI) (crashes/year)**	**Proportion of Collision Type (PDO)**	**Predicted N brsv (PDO) (crashes/year)**	**Predicted N brsv (TOTAL) (crashes/year)**
	from Table 12-6	(9)FI from Worksheet 1E	from Table 12-6	(9)PDO from Worksheet 1E	(9)TOTAL from Worksheet 1E
Total	1.000	0.504	1.000	1.974	2.478
		(2)*(3)FI		(4)*(5)PDO	(3)+(5)
Collision with animal	0.500	0.252	0.000	0.000	0.252
Collision with fixed object	0.000	0.000	0.111	0.219	0.219
Collision with other object	0.500	0.252	0.778	1.535	1.787
Other single-vehicle collision	0.000	0.000	0.111	0.219	0.219

Worksheet 1G -- Multiple-Vehicle Driveway-Related Collisions by Driveway Type for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
Driveway Type	**Number of driveways, n_j**	**Crashes per driveway per year, N_j**	**Coefficient for traffic adjustment, t**	**Initial N_{brdwy}**	**Overdispersion parameter, k**
		from Table 12-7	from Table 12-7	Equation 12-16 $n_j * N_j * (AADT/15{,}000)^t$	from Table 12-7
Major commercial	4	0.158	1.000	0.590	--
Minor commercial	8	0.050	1.000	0.373	
Major industrial/institutional	0	0.172	1.000	0.000	
Minor industrial/institutional	0	0.023	1.000	0.000	
Major residential	2	0.083	1.000	0.155	
Minor residential	58	0.016	1.000	0.866	
Other	0	0.025	1.000	0.000	
Total	--	--	--	1.984	0.81

Worksheet 1H -- Multiple-Vehicle Driveway-Related Collisions by Severity Level for Urban and Suburban Roadway Segments						
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Crash Severity Level	**Initial N_{brdwy}**	**Proportion of total crashes (f_{dwy})**	**Adjusted N_{brdwy}**	**Combined CMFs**	**Calibration factor, C_r**	**Predicted N_{brdwy}**
	$(5)_{TOTAL}$ from Worksheet 1G	from Table 12-7	$(2)_{TOTAL}$ * (3)	(6) from Worksheet 1B		(4)*(5)*(6)
Total	1.984	1.000	1.984	2.16	1.00	4.281
Fatal and injury (FI)	--	0.323	0.641	2.16	1.00	1.383
Property damage only (PDO)	--	0.677	1.343	2.16	1.00	2.898

Worksheet 1I -- Vehicle-Pedestrian Collisions for Urban and Suburban Roadway Segments							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Crash Severity Level	**Predicted N_{brmv}**	**Predicted N_{brsv}**	**Predicted N_{brdwy}**	**Predicted N_{br}**	**f_{pedr}**	**Calibration factor, C_r**	**Predicted N_{pedr}**
	(9) from Worksheet 1C	(9) from Worksheet 1E	(7) from Worksheet 1H	(2)+(3)+(4)	from Table 12-8		(5)*(6)*(7)
Total	6.359	2.478	4.281	13.118	0.036	1.00	0.472
Fatal and injury (FI)	--	--	--	--	--	1.00	0.472

Worksheet 1J -- Vehicle-Bicycle Collisions for Urban and Suburban Roadway Segments							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Crash Severity Level	**Predicted N_{brmv}**	**Predicted N_{brsv}**	**Predicted N_{brdwy}**	**Predicted N_{br}**	**f_{biker}**	**Calibration factor, C_r**	**Predicted N_{biker}**
	(9) from Worksheet 1C	(9) from Worksheet 1E	(7) from Worksheet 1H	(2)+(3)+(4)	from Table 12-9		(5)*(6)*(7)
Total	6.359	2.478	4.281	13.118	0.018	1.00	0.236
Fatal and injury (FI)	--	--	--	--	--	1.00	0.236

Worksheet 1K -- Crash Severity Distribution for Urban and Suburban Roadway Segments			
(1)	(2)	(3)	(4)
Collision type	**Fatal and injury (FI)**	**Property damage only (PDO)**	**Total**
	(3) from Worksheet 1D and 1F; (7) from Worksheet 1H; and (8) from Worksheet 1I and 1J	(5) from Worksheet 1D and 1F; and (7) from Worksheet 1H	(6) from Worksheet 1D and 1F; (7) from Worksheet 1H; and (8) from Worksheet 1I and 1J
MULTIPLE-VEHICLE			
Rear-end collisions (from Worksheet 1D)	0.928	1.501	2.429
Head-on collisions (from Worksheet 1D)	0.000	0.158	0.158
Angle collisions (from Worksheet 1D)	0.650	1.264	1.914
Sideswipe, same direction (from Worksheet 1D)	0.186	0.869	1.055
Sideswipe, opposite direction (from Worksheet 1D)	0.000	0.000	0.000
Driveway-related collisions (from Worksheet 1H)	1.383	2.898	4.281
Other multiple-vehicle collision (from Worksheet 1D)	0.093	0.711	0.804
Subtotal	3.239	7.401	10.640
SINGLE-VEHICLE			
Collision with animal (from Worksheet 1F)	0.252	0.000	0.252
Collision with fixed object (from Worksheet 1F)	0.000	0.219	0.219
Collision with other object (from Worksheet 1F)	0.252	1.535	1.787
Other single-vehicle collision (from Worksheet 1F)	0.000	0.219	0.219
Collision with pedestrian (from Worksheet 1I)	0.472	0.000	0.472
Collision with bicycle (from Worksheet 1J)	0.236	0.000	0.236
Subtotal	1.213	1.974	3.186
Total	4.451	9.375	13.826

Worksheet 1L -- Summary Results for Urban and Suburban Roadway Segments			
(1)	(2)	(3)	(4)
Crash Severity Level	**Predicted average crash frequency, $N_{predicted\ rs}$ (crashes/year)**	**Roadway segment length, L (mi)**	**Crash rate (crashes/mi/year)**
	(Total) from Worksheet 1K		(2) / (3)
Total	13.8	1.30	10.6
Fatal and injury (FI)	4.5	1.30	3.4
Property damage only (PDO)	9.4	1.30	7.2

Worksheet 3A -- Predicted Crashes by Severity and Site Type and Observed Crashes Using the Site-Specific EB Method for Urban and Suburban Arterials							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Collision type / Site type	**Predicted average crash frequency (crashes/year)**			**Observed crashes,** $N_{observed}$ (crashes/year)	**Overdispersion Parameter, k**	**Weighted adjustment, w**	**Expected average crash frequency,** $N_{expected}$
	$N_{predicted}$ (TOTAL)	$N_{predicted}$ (FI)	$N_{predicted}$ (PDO)			Equation A-5 from Part C Appendix	Equation A-4 from Part C Appendix
ROADWAY SEGMENTS							
Multiple-vehicle nondriveway							
Segment 1	6.359	1.856	4.503	22.56	0.840	0.158	20.002
Segment 2	0.000	0.000	0.000		0.840	1.000	0.000
Segment 3						1.000	0.000
Segment 4						1.000	0.000
Single-vehicle							
Segment 1	2.478	0.504	1.974	4.39	0.810	0.333	3.757
Segment 2	0.003	0.003	0.000		0.810	0.997	0.003
Segment 3						1.000	0.000
Segment 4						1.000	0.000
Multiple-vehicle driveway-related							
Segment 1	4.281	1.383	2.898	0.59	0.810	0.224	1.413
Segment 2	0.000	0.000	0.000		0.810	1.000	0.000
Segment 3						1.000	0.000
Segment 4						1.000	0.000
INTERSECTIONS							
Multiple-vehicle							
Intersection 1	0.000	0.000	0.000		0.800	1.000	0.000
Intersection 2	0.000	0.000	0.000		0.390	1.000	0.000
Intersection 3						1.000	0.000
Intersection 4						1.000	0.000
Single-vehicle							
Intersection 1	0.001	0.000	0.000		1.140	0.999	0.001
Intersection 2	0.000	0.000	0.000		0.360	1.000	0.000
Intersection 3						1.000	0.000
Intersection 4						1.000	0.000
COMBINED (sum of column)	13.122	3.746	9.375	28	--	--	25.176 per year

Worksheet 3B -- Predicted Pedestrian and Bicycle Crashes for Urban and Suburban Arterials		
(1)	(2)	(3)
Site Type	N_{ped}	N_{bike}
ROADWAY SEGMENTS		
Segment 1	0.472	0.236
Segment 2	0.000	0.000
Segment 3		
Segment 4		
INTERSECTIONS		
Intersection 1	0.000	0.000
Intersection 2	0.013	0.000
Intersection 3		
Intersection 4		
COMBINED (sum of column)	0.485	0.236

per year

Worksheet 3C -- Site-Specific EB Method Summary Results for Urban and Suburban Arterials					
(1)	(2)	(3)	(4)	(5)	(6)
Crash severity level	$N_{predicted}$	N_{ped}	N_{bike}	$N_{expected\ (VEHICLE)}$	$N_{expected}$
Total	$(2)_{COMB}$ from Worksheet 3A	$(2)_{COMB}$ from Worksheet 3B	$(3)_{COMB}$ from Worksheet 3B	$(8)_{COMB}$ Worksheet 3A	(3)+(4)+(5)
	13.1	0.5	0.2	25.2	25.9
Fatal and injury (FI)	$(3)_{COMB}$ from Worksheet 3A	$(2)_{COMB}$ from Worksheet 3B	$(3)_{COMB}$ from Worksheet 3B	$(5)_{TOTAL}$ * $(2)_{FI}$ / $(2)_{TOTAL}$	(3)+(4)+(5)
	3.7	0.5	0.2	7.2	7.9
Property damage only (PDO)	$(4)_{COMB}$ from Worksheet 3A	--	--	$(5)_{TOTAL}$ * $(2)_{PDO}$ / $(2)_{TOTAL}$	(3)+(4)+(5)
	9.4	0.0	0.0	18.0	18.0

Worksheet 3A -- Predicted Crashes by Severity and Crash Type and Observed Crashes Using the Site-Specific EB Method for Urban and Suburban Arterials								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(8)
Collision type / Site type	**Predicted average crash frequency (crashes/year)**			**Observed crashes,** $N_{observed}$ (crashes/year)	**Overdispersion Parameter, k**	**Weighted adjustment, w**	**Expected average crash frequency,** $N_{expected}$	**Expected average crash frequency, Adjusted**
	$N_{predicted}$ (TOTAL)	$N_{predicted}$ (FI)	$N_{predicted}$ (PDO)			Equation A-5 from Part C Appendix	Equation A-4 from Part C Appendix	
MULTIPLE VEHICLES								
Rear End	2.43	0.93	1.50	8.50	0.84	0.329	6.500	8.06
Head On	0.16	0.00	0.16	0.59	0.84	0.883	0.208	0.26
Angle	1.91	0.65	1.26	6.74	0.84	0.384	4.887	6.06
Sideswipe - Same Direction	1.05	0.19	0.87	3.81	0.84	0.530	2.348	2.91
Sideswipe - Opposite Direction	0.00	0.00	0.00	0.00	0.84	1.000	0.000	0.00
Driveway-related	4.28	1.38	2.90	0.59	0.81	0.224	1.413	1.75
Other multiple-vehicle	0.80	0.09	0.71	2.93	0.84	0.597	1.661	2.06
SINGLE VEHICLES								
Collision with animal	0.25	0.25	0.00	0.88	0.81	0.830	0.358	0.44
Collision with fixed object	0.22	0.00	0.22	0.29	0.81	0.849	0.230	0.29
Collision with other object	1.79	0.25	1.53	2.93	0.81	0.409	2.463	3.05
Other single-vehicle collision	0.22	0.00	0.22	0.29	0.81	0.849	0.230	0.29
Total	13.12	3.74	9.37				20.299	25.18

Worksheet 1A -- General Information and Input Data for Urban and Suburban Roadway Segments			
General Information		**Location Information**	
Analyst	TOPS Lab	Roadway	Lake Street
Agency or Company	TOPS	Roadway Section	5th Ave. South and 22nd Ave. South
Date Performed	01/06/13	Jurisdiction	Minneapolis, MN (Hennepin County)
		Analysis Year	

Input Data		**Base Conditions**	**Site Conditions**
Roadway type (2U, 3T, 4U, 4D, ST)		--	4U
Length of segment, L (mi)		--	1.48
AADT (veh/day)	$AADT_{MAX}$ = 40,100 (veh/day)	--	20,000
Type of on-street parking (none/parallel/angle)		None	Parallel (Comm/Ind)
Proportion of curb length with on-street parking		--	0.66
Median width (ft) - for divided only		15	Not Present
Lighting (present / not present)		Not Present	Present
Auto speed enforcement (present / not present)		Not Present	Not Present
Major commercial driveways (number)		--	8
Minor commercial driveways (number)		--	20
Major industrial / institutional driveways (number)		--	0
Minor industrial / institutional driveways (number)		--	0
Major residential driveways (number)		--	5
Minor residential driveways (number)		--	0
Other driveways (number)		--	0
Speed Category		--	Posted Speed 30 mph or Lower
Roadside fixed object density (fixed objects / mi)		0	160
Offset to roadside fixed objects (ft) [If greater than 30 or Not Present, input 30]		30	3
Calibration Factor, Cr		1.00	1.00

Worksheet 1B -- Crash Modification Factors for Urban and Suburban Roadway Segments

(1)	(2)	(3)	(4)	(5)	(6)
CMF for On-Street Parking	CMF for Roadside Fixed Objects	CMF for Median Width	CMF for Lighting	CMF for Automated Speed Enforcement	Combined CMF
CMF 1r	*CMF 2r*	*CMF 3r*	*CMF 4r*	*CMF 5r*	*CMF comb*
from Equation 12-32	from Equation 12-33	from Table 12-22	from Equation 12-34	from Section 12.7.1	(1)*(2)*(3)*(4)*(5)
1.47	2.04	1.00	0.92	1.00	2.74

Worksheet 1C -- Multiple-Vehicle Nondriveway Collisions by Severity Level for Urban and Suburban Roadway Segments

(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)
Crash Severity Level	**SPF Coefficients**		**Overdispersion Parameter, k**	**Initial N_{brmv}**	**Proportion of Total Crashes**	**Adjusted N_{brmv}**	**Combined CMFs**	**Calibration Factor, Cr**	**Predicted N_{brmv}**
	from Table 12-3		from Table 12-3	from Equation 12-10		$(4)_{TOTAL}$*(5)	(6) from Worksheet 1B		(6)*(7)*(8)
	a	b							
Total	-11.63	1.33	1.01	6.915	1.000	6.915	2.74	1.00	18.977
Fatal and Injury (FI)	-12.08	1.25	0.99	1.997	$(4)_{FI}/((4)_{FI}+(4)_{PDO})$ 0.302	2.089	2.74	1.00	5.733
Property Damage Only (PDO)	-12.53	1.38	1.08	4.613	$(5)_{TOTAL}-(5)_{FI}$ 0.698	4.826	2.74	1.00	13.245

Worksheet 1D -- Multiple-Vehicle Nondriveway Collisions by Collision Type for Urban and Suburban Roadway Segments

(1)	(2)	(3)	(4)	(5)	(6)
Collision Type	**Proportion of Collision Type(FI)**	**Predicted $N_{brmv\ (FI)}$ (crashes/year)**	**Proportion of Collision Type (PDO)**	**Predicted $N_{brmv\ (PDO)}$ (crashes/year)**	**Predicted $N_{brmv\ (TOTAL)}$ (crashes/year)**
	from Table 12-4	$(9)_{FI}$ from Worksheet 1C	from Table 12-4	$(9)_{PDO}$ from Worksheet 1C	$(9)_{TOTAL}$ from Worksheet 1C
Total	1.000	5.733	1.000	13.245	18.977
		$(2)*(3)_{FI}$		$(4)*(5)_{PDO}$	(3)+(5)
Rear-end collision	0.354	2.028	0.232	3.069	5.098
Head-on collision	0.069	0.397	0.013	0.168	0.565
Angle collision	0.362	2.073	0.248	3.280	5.352
Sideswipe, same direction	0.054	0.309	0.149	1.976	2.285
Sideswipe, opposite direction	0.023	0.132	0.022	0.294	0.427
Other multiple-vehicle collision	0.138	0.794	0.337	4.457	5.251

Worksheet 1E -- Single-Vehicle Collisions by Severity Level for Urban and Suburban Roadway Segments

(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)
Crash Severity Level	**SPF Coefficients**		**Overdispersion Parameter, k**	**Initial N_{brsv}**	**Proportion of Total Crashes**	**Adjusted N_{brsv}**	**Combined CMFs**	**Calibration Factor, Cr**	**Predicted N_{brsv}**
	from Table 12-5		from Table 12-5	from Equation 12-13		$(4)_{TOTAL}*(5)$	(6) from Worksheet 1B		(6)*(7)*(8)
	a	b							
Total	-7.99	0.81	0.91	1.528	1.000	1.528	2.74	1.00	4.193
Fatal and Injury (FI)	-7.37	0.61	0.54	0.392	$(4)_{FI}/((4)_{FI}+(4)_{PDO})$ 0.241	0.368	2.74	1.00	1.010
Property Damage Only (PDO)	-8.50	0.84	0.97	1.235	$(5)_{TOTAL}-(5)_{FI}$ 0.759	1.160	2.74	1.00	3.183

Worksheet 1F -- Single-Vehicle Collisions by Collision Type for Urban and Suburban Roadway Segments

(1)	(2)	(3)	(4)	(5)	(6)
Collision Type	**Proportion of Collision Type(FI)**	**Predicted $N_{brsv\ (FI)}$ (crashes/year)**	**Proportion of Collision Type (PDO)**	**Predicted $N_{brsv\ (PDO)}$ (crashes/year)**	**Predicted $N_{brsv\ (TOTAL)}$ (crashes/year)**
	from Table 12-6	$(9)_{FI}$ from Worksheet 1E	from Table 12-6	$(9)_{PDO}$ from Worksheet 1E	$(9)_{TOTAL}$ from Worksheet 1E
Total	1.000	1.010	1.000	3.183	4.193
		$(2)*(3)_{FI}$		$(4)*(5)_{PDO}$	(3)+(5)
Collision with animal	0.000	0.000	0.000	0.000	0.000
Collision with fixed object	0.818	0.826	0.632	2.010	2.837
Collision with other object	0.182	0.184	0.368	1.173	1.356
Other single-vehicle collision	0.000	0.000	0.000	0.000	0.000

Worksheet 1G -- Multiple-Vehicle Driveway-Related Collisions by Driveway Type for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
Driveway Type	**Number of driveways, n_j**	**Crashes per driveway per year, N_j**	**Coefficient for traffic adjustment, t**	**Initial N_{brdwy}**	**Overdispersion parameter, k**
		from Table 12-7	from Table 12-7	Equation 12-16 $n_j * N_j * (AADT/15,000)^t$	from Table 12-7
Major commercial	8	0.182	1.172	2.040	--
Minor commercial	20	0.058	1.172	1.625	
Major industrial/institutional	0	0.198	1.172	0.000	
Minor industrial/institutional	0	0.026	1.172	0.000	
Major residential	5	0.096	1.172	0.672	
Minor residential	0	0.018	1.172	0.000	
Other	0	0.029	1.172	0.000	
Total	--	--	--	4.337	0.81

Worksheet 1H -- Multiple-Vehicle Driveway-Related Collisions by Severity Level for Urban and Suburban Roadway Segments						
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Crash Severity Level	**Initial N_{brdwy}**	**Proportion of total crashes (f_{dwy})**	**Adjusted N_{brdwy}**	**Combined CMFs**	**Calibration factor, C_r**	**Predicted N_{brdwy}**
	$(5)_{TOTAL}$ from Worksheet 1G	from Table 12-7	$(2)_{TOTAL}$ * (3)	(6) from Worksheet 1B		(4)*(5)*(6)
Total	4.337	1.000	4.337	2.74	1.00	11.904
Fatal and injury (FI)	--	0.342	1.483	2.74	1.00	4.071
Property damage only (PDO)	--	0.658	2.854	2.74	1.00	7.833

Worksheet 1I -- Vehicle-Pedestrian Collisions for Urban and Suburban Roadway Segments							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Crash Severity Level	**Predicted N_{brmv}**	**Predicted N_{brsv}**	**Predicted N_{brdwy}**	**Predicted N_{br}**	**f_{pedr}**	**Calibration factor, C_r**	**Predicted N_{pedr}**
	(9) from Worksheet 1C	(9) from Worksheet 1E	(7) from Worksheet 1H	(2)+(3)+(4)	from Table 12-8		(5)*(6)*(7)
Total	18.977	4.193	11.904	35.074	0.022	1.00	0.772
Fatal and injury (FI)	--	--	--	--	--	1.00	0.772

Worksheet 1J -- Vehicle-Bicycle Collisions for Urban and Suburban Roadway Segments							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Crash Severity Level	**Predicted N_{brmv}**	**Predicted N_{brsv}**	**Predicted N_{brdwy}**	**Predicted N_{br}**	**f_{biker}**	**Calibration factor, C_r**	**Predicted N_{biker}**
	(9) from Worksheet 1C	(9) from Worksheet 1E	(7) from Worksheet 1H	(2)+(3)+(4)	from Table 12-9		(5)*(6)*(7)
Total	18.977	4.193	11.904	35.074	0.011	1.00	0.386
Fatal and injury (FI)	--	--	--	--	--	1.00	0.386

Worksheet 1K -- Crash Severity Distribution for Urban and Suburban Roadway Segments			
(1)	(2)	(3)	(4)
Collision type	**Fatal and injury (FI)**	**Property damage only (PDO)**	**Total**
	(3) from Worksheet 1D and 1F; (7) from Worksheet 1H; and (8) from Worksheet 1I and 1J	(5) from Worksheet 1D and 1F; and (7) from Worksheet 1H	(6) from Worksheet 1D and 1F; (7) from Worksheet 1H; and (8) from Worksheet 1I and 1J
MULTIPLE-VEHICLE			
Rear-end collisions (from Worksheet 1D)	2.028	3.069	5.098
Head-on collisions (from Worksheet 1D)	0.397	0.168	0.565
Angle collisions (from Worksheet 1D)	2.073	3.280	5.352
Sideswipe, same direction (from Worksheet 1D)	0.309	1.976	2.285
Sideswipe, opposite direction (from Worksheet 1D)	0.132	0.294	0.427
Driveway-related collisions (from Worksheet 1H)	4.071	7.833	11.904
Other multiple-vehicle collision (from Worksheet 1D)	0.794	4.457	5.251
Subtotal	9.804	21.077	30.881
SINGLE-VEHICLE			
Collision with animal (from Worksheet 1F)	0.000	0.000	0.000
Collision with fixed object (from Worksheet 1F)	0.826	2.010	2.837
Collision with other object (from Worksheet 1F)	0.184	1.173	1.356
Other single-vehicle collision (from Worksheet 1F)	0.000	0.000	0.000
Collision with pedestrian (from Worksheet 1I)	0.772	0.000	0.772
Collision with bicycle (from Worksheet 1J)	0.386	0.000	0.386
Subtotal	2.168	3.183	5.350
Total	11.971	24.260	36.231

Worksheet 1L -- Summary Results for Urban and Suburban Roadway Segments			
(1)	(2)	(3)	(4)
Crash Severity Level	**Predicted average crash frequency, $N_{predicted\ rs}$ (crashes/year)**	**Roadway segment length, L (mi)**	**Crash rate (crashes/mi/year)**
	(Total) from Worksheet 1K		(2) / (3)
Total	36.2	1.48	24.5
Fatal and injury (FI)	12.0	1.48	8.1
Property damage only (PDO)	24.3	1.48	16.4

Worksheet 3A -- Predicted Crashes by Severity and Site Type and Observed Crashes Using the Site-Specific EB Method for Urban and Suburban Arterials								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
Collision type / Site type	Predicted average crash frequency (crashes/year)			Observed crashes, $N_{observed}$ (crashes/year)	Overdispersion Parameter, k	Weighted adjustment, w	Expected average crash frequency, $N_{expected}$	
	$N_{predicted}$ (TOTAL)	$N_{predicted}$ (FI)	$N_{predicted}$ (PDO)			Equation A-5 from Part C Appendix	Equation A-4 from Part C Appendix	
ROADWAY SEGMENTS								
Multiple-vehicle nondriveway								
Segment 1	18.977	5.733	13.245	130.36	1.010	0.050	124.834	
Segment 2	0.000	0.000	0.000		0.840	1.000	0.000	
Segment 3						1.000	0.000	
Segment 4						1.000	0.000	
Single-vehicle								
Segment 1	4.193	1.010	3.183	8.79	0.910	0.208	7.834	
Segment 2	0.003	0.003	0.000		0.810	0.997	0.003	
Segment 3						1.000	0.000	
Segment 4						1.000	0.000	
Multiple-vehicle driveway-related								
Segment 1	11.904	4.071	7.833	3.22	0.810	0.094	4.038	
Segment 2	0.000	0.000	0.000		0.810	1.000	0.000	
Segment 3						1.000	0.000	
Segment 4						1.000	0.000	
INTERSECTIONS								
Multiple-vehicle								
Intersection 1	0.000	0.000	0.000		0.800	1.000	0.000	
Intersection 2	0.000	0.000	0.000		0.390	1.000	0.000	
Intersection 3						1.000	0.000	
Intersection 4						1.000	0.000	
Single-vehicle								
Intersection 1	0.001	0.000	0.000		1.140	0.999	0.001	
Intersection 2	0.000	0.000	0.000		0.360	1.000	0.000	
Intersection 3						1.000	0.000	
Intersection 4						1.000	0.000	
COMBINED (sum of column)	35.078	10.817	24.261	142	--	--	136.711	per year

Worksheet 3B -- Predicted Pedestrian and Bicycle Crashes for Urban and Suburban Arterials

(1) Site Type	(2) N_{ped}	(3) N_{bike}	
ROADWAY SEGMENTS			
Segment 1	0.772	0.386	
Segment 2	0.000	0.000	
Segment 3			
Segment 4			
INTERSECTIONS			
Intersection 1	0.000	0.000	
Intersection 2	0.013	0.000	
Intersection 3			
Intersection 4			
COMBINED (sum of column)	0.784	0.386	per year

Worksheet 3C -- Site-Specific EB Method Summary Results for Urban and Suburban Arterials

(1)	(2)	(3)	(4)	(5)	(6)
Crash severity level	**$N_{predicted}$**	**N_{ped}**	**N_{bike}**	$N_{expected (VEHICLE)}$	$N_{expected}$
Total	$(2)_{COMB}$ from Worksheet 3A	$(2)_{COMB}$ from Worksheet 3B	$(3)_{COMB}$ from Worksheet 3B	$(8)_{COMB}$ Worksheet 3A	(3)+(4)+(5)
	35.1	0.8	0.4	136.7	137.9
Fatal and injury (FI)	$(3)_{COMB}$ from Worksheet 3A	$(2)_{COMB}$ from Worksheet 3B	$(3)_{COMB}$ from Worksheet 3B	$(5)_{TOTAL}$ * $(2)_{FI}$ / $(2)_{TOTAL}$	(3)+(4)+(5)
	10.8	0.8	0.4	42.2	43.3
Property damage only (PDO)	$(4)_{COMB}$ from Worksheet 3A	--	--	$(5)_{TOTAL}$ * $(2)_{PDO}$ / $(2)_{TOTAL}$	(3)+(4)+(5)
	24.3	0.0	0.0	94.6	94.6

Worksheet 3A -- Predicted Crashes by Severity and Crash Type and Observed Crashes Using the Site-Specific EB Method for Urban and Suburban Arterials

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(8)
Collision type / Site type	**Predicted average crash frequency (crashes/year)**			**Observed crashes,** $N_{observed}$ (crashes/year)	**Overdispersion Parameter, k**	**Weighted adjustment, w**	**Expected average crash frequency,** $N_{expected}$	**Expected average crash frequency, Adjusted**
	$N_{predicted}$ (TOTAL)	$N_{predicted}$ (FI)	$N_{predicted}$ (PDO)			Equation A-5 from Part C Appendix	Equation A-4 from Part C Appendix	
MULTIPLE VEHICLES								
Rear End	5.10	2.03	3.07	34.86	1.01	0.163	30.019	34.45
Head On	0.57	0.40	0.17	3.81	1.01	0.637	1.743	2.00
Angle	5.35	2.07	3.28	36.62	1.01	0.156	31.736	36.42
Sideswipe - Same Direction	2.28	0.31	1.98	15.82	1.01	0.302	11.727	13.46
Sideswipe - Opposite Direction	0.43	0.13	0.29	2.93	1.01	0.699	1.180	1.35
Driveway-related	11.90	4.07	7.83	3.22	0.81	0.094	4.038	4.63
Other multiple-vehicle	5.25	0.79	4.46	36.32	1.01	0.159	31.394	36.03
SINGLE VEHICLES								
Collision with animal	0.00	0.00	0.00	0.00	0.91	1.000	0.000	0.00
Collision with fixed object	2.84	0.83	2.01	6.15	0.91	0.279	5.226	6.00
Collision with other object	1.36	0.18	1.17	2.64	0.91	0.448	2.063	2.37
Other single-vehicle collision	0.00	0.00	0.00	0.00	0.91	1.000	0.000	0.00
Total	35.07	10.81	24.26				119.129	136.71

Worksheet 1A -- General Information and Input Data for Urban and Suburban Roadway Segments			
General Information		**Location Information**	
Analyst	Ghazan Khan	Roadway	76th St.
Agency or Company	TOPS	Roadway Section	Xerxes Ave. South and 12th Ave. South
Date Performed	01/06/13	Jurisdiction	Richfield, MN
		Analysis Year	

Input Data		**Base Conditions**	**Site Conditions**
Roadway type (2U, 3T, 4U, 4D, ST)		--	4U
Length of segment, L (mi)		--	1.9
AADT (veh/day)	$AADT_{MAX}$ = 40,100 (veh/day)	--	4,000
Type of on-street parking (none/parallel/angle)		None	Parallel (Residential)
Proportion of curb length with on-street parking		--	0.66
Median width (ft) - for divided only		15	Not Present
Lighting (present / not present)		Not Present	Present
Auto speed enforcement (present / not present)		Not Present	Not Present
Major commercial driveways (number)		--	6
Minor commercial driveways (number)		--	6
Major industrial / institutional driveways (number)		--	0
Minor industrial / institutional driveways (number)		--	0
Major residential driveways (number)		--	3
Minor residential driveways (number)		--	99
Other driveways (number)		--	0
Speed Category		--	Posted Speed 30 mph or Lower
Roadside fixed object density (fixed objects / mi)		0	293
Offset to roadside fixed objects (ft) [If greater than 30 or Not Present, input 30]		30	6
Calibration Factor, Cr		1.00	1.00

Worksheet 1B -- Crash Modification Factors for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
CMF for On-Street Parking	CMF for Roadside Fixed Objects	CMF for Median Width	CMF for Lighting	CMF for Automated Speed Enforcement	Combined CMF
CMF 1r	*CMF 2r*	*CMF 3r*	*CMF 4r*	*CMF 5r*	*CMF comb*
from Equation 12-32	from Equation 12-33	from Table 12-22	from Equation 12-34	from Section 12.7.1	(1)*(2)*(3)*(4)*(5)
1.07	2.25	1.00	0.92	1.00	2.20

Worksheet 1C -- Multiple-Vehicle Nondriveway Collisions by Severity Level for Urban and Suburban Roadway Segments									
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)
Crash Severity Level	**SPF Coefficients**		**Overdispersion Parameter, k**	**Initial N_{brmv}**	**Proportion of Total Crashes**	**Adjusted N_{brmv}**	**Combined CMFs**	**Calibration Factor, Cr**	**Predicted N_{brmv}**
	from Table 12-3		from Table 12-3	from Equation 12-10		$(4)_{TOTAL}$*(5)	(6) from Worksheet 1B		(6)*(7)*(8)
	a	b							
Total	-11.63	1.33	1.01	1.044	1.000	1.044	2.20	1.00	2.296
Fatal and Injury (FI)	-12.08	1.25	0.99	0.343	$(4)_{FI}/((4)_{FI}+(4)_{PDO})$ 0.348	0.363	2.20	1.00	0.799
Property Damage Only (PDO)	-12.53	1.38	1.08	0.643	$(5)_{TOTAL}-(5)_{FI}$ 0.652	0.681	2.20	1.00	1.497

Worksheet 1D -- Multiple-Vehicle Nondriveway Collisions by Collision Type for Urban and Suburban Roadway Segments

(1)	(2)	(3)	(4)	(5)	(6)
Collision Type	**Proportion of Collision Type$_{(FI)}$**	**Predicted N $_{brmv\ (FI)}$ (crashes/year)**	**Proportion of Collision Type $_{(PDO)}$**	**Predicted N $_{brmv\ (PDO)}$ (crashes/year)**	**Predicted N $_{brmv\ (TOTAL)}$ (crashes/year)**
	from Table 12-4	(9)$_{FI}$ from Worksheet 1C	from Table 12-4	(9)$_{PDO}$ from Worksheet 1C	(9)$_{TOTAL}$ from Worksheet 1C
Total	1.000	0.799	1.000	1.497	2.296
		(2)*(3)$_{FI}$		(4)*(5)$_{PDO}$	(3)+(5)
Rear-end collision	0.511	0.408	0.506	0.758	1.166
Head-on collision	0.077	0.062	0.004	0.006	0.067
Angle collision	0.181	0.145	0.130	0.195	0.339
Sideswipe, same direction	0.093	0.074	0.249	0.373	0.447
Sideswipe, opposite direction	0.082	0.066	0.031	0.046	0.112
Other multiple-vehicle collision	0.056	0.045	0.080	0.120	0.165

Worksheet 1E -- Single-Vehicle Collisions by Severity Level for Urban and Suburban Roadway Segments

(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)
Crash Severity Level	**SPF Coefficients**		**Overdispersion Parameter, k**	**Initial N_{brsv}**	**Proportion of Total Crashes**	**Adjusted N_{brsv}**	**Combined CMFs**	**Calibration Factor, Cr**	**Predicted N_{brsv}**
	from Table 12-5		from Table 12-5	from Equation 12-13		(4)$_{TOTAL}$*(5)	(6) from Worksheet 1B		(6)*(7)*(8)
	a	b							
Total	-7.99	0.81	0.91	0.533	1.000	0.533	2.20	1.00	1.172
Fatal and Injury (FI)	-7.37	0.61	0.54	0.188	(4)$_{FI}$/((4)$_{FI}$+(4)$_{PDO}$) 0.315	0.168	2.20	1.00	0.369
Property Damage Only (PDO)	-8.50	0.84	0.97	0.410	(5)$_{TOTAL}$-(5)$_{FI}$ 0.685	0.365	2.20	1.00	0.803

Worksheet 1F -- Single-Vehicle Collisions by Collision Type for Urban and Suburban Roadway Segments

(1)	(2)	(3)	(4)	(5)	(6)
Collision Type	**Proportion of Collision Type$_{(FI)}$**	**Predicted N $_{brsv\ (FI)}$ (crashes/year)**	**Proportion of Collision Type $_{(PDO)}$**	**Predicted N $_{brsv\ (PDO)}$ (crashes/year)**	**Predicted N $_{brsv\ (TOTAL)}$ (crashes/year)**
	from Table 12-6	(9)$_{FI}$ from Worksheet 1E	from Table 12-6	(9)$_{PDO}$ from Worksheet 1E	(9)$_{TOTAL}$ from Worksheet 1E
Total	1.000	0.369	1.000	0.803	1.172
		(2)*(3)$_{FI}$		(4)*(5)$_{PDO}$	(3)+(5)
Collision with animal	0.001	0.000	0.001	0.001	0.001
Collision with fixed object	0.612	0.226	0.809	0.649	0.875
Collision with other object	0.020	0.007	0.029	0.023	0.031
Other single-vehicle collision	0.367	0.135	0.161	0.129	0.265

Worksheet 1G -- Multiple-Vehicle Driveway-Related Collisions by Driveway Type for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
Driveway Type	**Number of driveways, n_j**	**Crashes per driveway per year, N_j**	**Coefficient for traffic adjustment, t**	**Initial N_{brdwy}**	**Overdispersion parameter, k**
		from Table 12-7	from Table 12-7	Equation 12-16 $n_j * N_j * (AADT/15,000)^t$	from Table 12-7
Major commercial	6	0.182	1.172	0.232	--
Minor commercial	6	0.058	1.172	0.074	
Major industrial/institutional	0	0.198	1.172	0.000	
Minor industrial/institutional	0	0.026	1.172	0.000	
Major residential	3	0.096	1.172	0.061	
Minor residential	99	0.018	1.172	0.379	
Other	0	0.029	1.172	0.000	
Total	--	--	--	0.746	0.81

Worksheet 1H -- Multiple-Vehicle Driveway-Related Collisions by Severity Level for Urban and Suburban Roadway Segments						
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Crash Severity Level	**Initial N_{brdwy}**	**Proportion of total crashes (f_{dwy})**	**Adjusted N_{brdwy}**	**Combined CMFs**	**Calibration factor, C_r**	**Predicted N_{brdwy}**
	$(5)_{TOTAL}$ from Worksheet 1G	from Table 12-7	$(2)_{TOTAL}$ * (3)	(6) from Worksheet 1B		(4)*(5)*(6)
Total	0.746	1.000	0.746	2.20	1.00	1.640
Fatal and injury (FI)	--	0.342	0.255	2.20	1.00	0.561
Property damage only (PDO)	--	0.658	0.491	2.20	1.00	1.079

Worksheet 1I -- Vehicle-Pedestrian Collisions for Urban and Suburban Roadway Segments							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Crash Severity Level	**Predicted N_{brmv}**	**Predicted N_{brsv}**	**Predicted N_{brdwy}**	**Predicted N_{br}**	**f_{pedr}**	**Calibration factor, C_r**	**Predicted N_{pedr}**
	(9) from Worksheet 1C	(9) from Worksheet 1E	(7) from Worksheet 1H	(2)+(3)+(4)	from Table 12-8		(5)*(6)*(7)
Total	2.296	1.172	1.640	5.108	0.022	1.00	0.112
Fatal and injury (FI)	--	--	--	--	--	1.00	0.112

Worksheet 1J -- Vehicle-Bicycle Collisions for Urban and Suburban Roadway Segments							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Crash Severity Level	**Predicted N_{brmv}**	**Predicted N_{brsv}**	**Predicted N_{brdwy}**	**Predicted N_{br}**	**f_{biker}**	**Calibration factor, C_r**	**Predicted N_{biker}**
	(9) from Worksheet 1C	(9) from Worksheet 1E	(7) from Worksheet 1H	(2)+(3)+(4)	from Table 12-9		(5)*(6)*(7)
Total	2.296	1.172	1.640	5.108	0.011	1.00	0.056
Fatal and injury (FI)	--	--	--	--	--	1.00	0.056

Worksheet 1K -- Crash Severity Distribution for Urban and Suburban Roadway Segments			
(1)	(2)	(3)	(4)
Collision type	**Fatal and injury (FI)**	**Property damage only (PDO)**	**Total**
	(3) from Worksheet 1D and 1F; (7) from Worksheet 1H; and (8) from Worksheet 1I and 1J	(5) from Worksheet 1D and 1F; and (7) from Worksheet 1H	(6) from Worksheet 1D and 1F; (7) from Worksheet 1H; and (8) from Worksheet 1I and 1J
MULTIPLE-VEHICLE			
Rear-end collisions (from Worksheet 1D)	0.408	0.758	1.166
Head-on collisions (from Worksheet 1D)	0.062	0.006	0.067
Angle collisions (from Worksheet 1D)	0.145	0.195	0.339
Sideswipe, same direction (from Worksheet 1D)	0.074	0.373	0.447
Sideswipe, opposite direction (from Worksheet 1D)	0.066	0.046	0.112
Driveway-related collisions (from Worksheet 1H)	0.561	1.079	1.640
Other multiple-vehicle collision (from Worksheet 1D)	0.045	0.120	0.165
Subtotal	1.360	2.576	3.936
SINGLE-VEHICLE			
Collision with animal (from Worksheet 1F)	0.000	0.001	0.001
Collision with fixed object (from Worksheet 1F)	0.226	0.649	0.875
Collision with other object (from Worksheet 1F)	0.007	0.023	0.031
Other single-vehicle collision (from Worksheet 1F)	0.135	0.129	0.265
Collision with pedestrian (from Worksheet 1I)	0.112	0.000	0.112
Collision with bicycle (from Worksheet 1J)	0.056	0.000	0.056
Subtotal	0.537	0.803	1.340
Total	1.897	3.379	5.276

Worksheet 1L -- Summary Results for Urban and Suburban Roadway Segments			
(1)	(2)	(3)	(4)
Crash Severity Level	**Predicted average crash frequency, $N_{predicted\ rs}$ (crashes/year)**	**Roadway segment length, L (mi)**	**Crash rate (crashes/mi/year)**
	(Total) from Worksheet 1K		(2) / (3)
Total	5.3	1.90	2.8
Fatal and injury (FI)	1.9	1.90	1.0
Property damage only (PDO)	3.4	1.90	1.8

Worksheet 3A -- Predicted Crashes by Severity and Site Type and Observed Crashes Using the Site-Specific EB Method for Urban and Suburban Arterials								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
Collision type / Site type	Predicted average crash frequency (crashes/year)			Observed crashes, $N_{observed}$ (crashes/year)	Overdispersion Parameter, k	Weighted adjustment, w	Expected average crash frequency, $N_{expected}$	
	$N_{predicted}$ (TOTAL)	$N_{predicted}$ (FI)	$N_{predicted}$ (PDO)			Equation A-5 from Part C Appendix	Equation A-4 from Part C Appendix	
ROADWAY SEGMENTS								
Multiple-vehicle nondriveway								
Segment 1	2.296	0.799	1.497	12.03	1.010	0.301	9.099	
Segment 2	0.000	0.000	0.000		0.840	1.000	0.000	
Segment 3						1.000	0.000	
Segment 4						1.000	0.000	
Single-vehicle								
Segment 1	1.172	0.369	0.803	2.01	0.910	0.484	1.602	
Segment 2	0.003	0.003	0.000		0.810	0.997	0.003	
Segment 3						1.000	0.000	
Segment 4						1.000	0.000	
Multiple-vehicle driveway-related								
Segment 1	1.640	0.561	1.079	0.00	0.810	0.429	0.704	
Segment 2	0.000	0.000	0.000		0.810	1.000	0.000	
Segment 3						1.000	0.000	
Segment 4						1.000	0.000	
INTERSECTIONS								
Multiple-vehicle								
Intersection 1	0.000	0.000	0.000		0.800	1.000	0.000	
Intersection 2	0.000	0.000	0.000		0.390	1.000	0.000	
Intersection 3						1.000	0.000	
Intersection 4						1.000	0.000	
Single-vehicle								
Intersection 1	0.001	0.000	0.000		1.140	0.999	0.001	
Intersection 2	0.000	0.000	0.000		0.360	1.000	0.000	
Intersection 3						1.000	0.000	
Intersection 4						1.000	0.000	
COMBINED (sum of column)	5.112	1.732	3.380	14	--	--	11.410	per year

Worksheet 3B -- Predicted Pedestrian and Bicycle Crashes for Urban and Suburban Arterials

(1)	(2)	(3)	
Site Type	**N_{ped}**	**N_{bike}**	
ROADWAY SEGMENTS			
Segment 1	0.112	0.056	
Segment 2	0.000	0.000	
Segment 3			
Segment 4			
INTERSECTIONS			
Intersection 1	0.000	0.000	
Intersection 2	0.013	0.000	
Intersection 3			
Intersection 4			
COMBINED (sum of column)	0.125	0.056	per year

Worksheet 3C -- Site-Specific EB Method Summary Results for Urban and Suburban Arterials

(1)	(2)	(3)	(4)	(5)	(6)
Crash severity level	**$N_{predicted}$**	**N_{ped}**	**N_{bike}**	$N_{expected\ (VEHICLE)}$	$N_{expected}$
Total	$(2)_{COMB}$ from Worksheet 3A	$(2)_{COMB}$ from Worksheet 3B	$(3)_{COMB}$ from Worksheet 3B	$(8)_{COMB}$ Worksheet 3A	(3)+(4)+(5)
	5.1	0.1	0.1	11.4	11.6
Fatal and injury (FI)	$(3)_{COMB}$ from Worksheet 3A	$(2)_{COMB}$ from Worksheet 3B	$(3)_{COMB}$ from Worksheet 3B	$(5)_{TOTAL}$ * $(2)_{FI}$ / $(2)_{TOTAL}$	(3)+(4)+(5)
	1.7	0.1	0.1	3.9	4.0
Property damage only (PDO)	$(4)_{COMB}$ from Worksheet 3A	--	--	$(5)_{TOTAL}$ * $(2)_{PDO}$ / $(2)_{TOTAL}$	(3)+(4)+(5)
	3.4	0.0	0.0	7.5	7.5

Worksheet 3A -- Predicted Crashes by Severity and Crash Type and Observed Crashes Using the Site-Specific EB Method for Urban and Suburban Arterials

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(8)
Collision type / Site type	**Predicted average crash frequency (crashes/year)**			**Observed crashes,** $N_{observed}$ (crashes/year)	**Overdispersion Parameter, k**	**Weighted adjustment, w**	**Expected average crash frequency, $N_{expected}$**	**Expected average crash frequency, Adjusted**
	$N_{predicted}$ (TOTAL)	$N_{predicted}$ (FI)	$N_{predicted}$ (PDO)			Equation A-5 from Part C Appendix	Equation A-4 from Part C Appendix	
MULTIPLE VEHICLES								
Rear End	1.17	0.41	0.76	2.01	1.01	0.459	1.620	2.49
Head On	0.07	0.06	0.01	0.00	1.01	0.936	0.063	0.10
Angle	0.34	0.14	0.19	9.02	1.01	0.745	2.556	3.93
Sideswipe - Same Direction	0.45	0.07	0.37	1.00	1.01	0.689	0.620	0.95
Sideswipe - Opposite Direction	0.11	0.07	0.05	0.00	1.01	0.898	0.101	0.15
Driveway-related	1.64	0.56	1.08	0.00	0.81	0.429	0.704	1.08
Other multiple-vehicle	0.16	0.04	0.12	0.00	1.01	0.858	0.141	0.22
SINGLE VEHICLES								
Collision with animal	0.00	0.00	0.00	0.00	0.91	0.999	0.001	0.00
Collision with fixed object	0.88	0.23	0.65	2.01	0.91	0.557	1.376	2.11
Collision with other object	0.03	0.01	0.02	0.00	0.91	0.973	0.030	0.05
Other single-vehicle collision	0.26	0.14	0.13	0.00	0.91	0.806	0.213	0.33
Total	5.11	1.73	3.38				7.425	11.41

Worksheet 1A -- General Information and Input Data for Urban and Suburban Roadway Segments

General Information		Location Information	
Analyst	TOPS Lab	Roadway	TH 169
Agency or Company	TOPS	Roadway Section	W. Jackson St. to W. Union St.
Date Performed	01/06/13	Jurisdiction	St. Peter, MN
		Analysis Year	

Input Data		Base Conditions	Site Conditions
Roadway type (2U, 3T, 4U, 4D, ST)		--	4D
Length of segment, L (mi)		--	1.6
AADT (veh/day)	$AADT_{MAX}$ = 66,000 (veh/day)	--	20,000
Type of on-street parking (none/parallel/angle)		None	None
Proportion of curb length with on-street parking		--	0.66
Median width (ft) - for divided only		15	Not Present
Lighting (present / not present)		Not Present	Not Present
Auto speed enforcement (present / not present)		Not Present	Not Present
Major commercial driveways (number)		--	5
Minor commercial driveways (number)		--	10
Major industrial / institutional driveways (number)		--	0
Minor industrial / institutional driveways (number)		--	0
Major residential driveways (number)		--	0
Minor residential driveways (number)		--	14
Other driveways (number)		--	0
Speed Category		--	Posted Speed 30 mph or Lower
Roadside fixed object density (fixed objects / mi)		0	284
Offset to roadside fixed objects (ft) [If greater than 30 or Not Present, input 30]		30	6
Calibration Factor, Cr		1.00	1.00

Worksheet 1B -- Crash Modification Factors for Urban and Suburban Roadway Segments

(1)	(2)	(3)	(4)	(5)	(6)
CMF for On-Street Parking	CMF for Roadside Fixed Objects	CMF for Median Width	CMF for Lighting	CMF for Automated Speed Enforcement	Combined CMF
CMF 1r	*CMF 2r*	*CMF 3r*	*CMF 4r*	*CMF 5r*	*CMF comb*
from Equation 12-32	from Equation 12-33	from Table 12-22	from Equation 12-34	from Section 12.7.1	(1)*(2)*(3)*(4)*(5)
1.00	2.18	1.00	1.00	1.00	2.18

Worksheet 1C -- Multiple-Vehicle Nondriveway Collisions by Severity Level for Urban and Suburban Roadway Segments

(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)
Crash Severity Level	**SPF Coefficients**		**Overdispersion Parameter, k**	**Initial N_{brmv}**	**Proportion of Total Crashes**	**Adjusted N_{brmv}**	**Combined CMFs**	**Calibration Factor, Cr**	**Predicted N_{brmv}**
	from Table 12-3		from Table 12-3	from Equation 12-10		$(4)_{TOTAL}$*(5)	(6) from Worksheet 1B		(6)*(7)*(8)
	a	b							
Total	-12.34	1.36	1.32	4.947	1.000	4.947	2.18	1.00	10.771
Fatal and Injury (FI)	-12.76	1.28	1.31	1.472	$(4)_{FI}/((4)_{FI}+(4)_{PDO})$ 0.281	1.389	2.18	1.00	3.025
Property Damage Only (PDO)	-12.81	1.38	1.34	3.769	$(5)_{TOTAL}-(5)_{FI}$ 0.719	3.558	2.18	1.00	7.746

Worksheet 1D -- Multiple-Vehicle Nondriveway Collisions by Collision Type for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
Collision Type	**Proportion of Collision Type$_{(FI)}$**	**Predicted $N_{brmv\ (FI)}$ (crashes/year)**	**Proportion of Collision Type $_{(PDO)}$**	**Predicted $N_{brmv\ (PDO)}$ (crashes/year)**	**Predicted $N_{brmv\ (TOTAL)}$ (crashes/year)**
	from Table 12-4	$(9)_{FI}$ from Worksheet 1C	from Table 12-4	$(9)_{PDO}$ from Worksheet 1C	$(9)_{TOTAL}$ from Worksheet 1C
Total	1.000	3.025	1.000	7.746	10.771
		$(2)*(3)_{FI}$		$(4)*(5)_{PDO}$	(3)+(5)
Rear-end collision	0.467	1.412	0.559	4.333	5.744
Head-on collision	0.000	0.000	0.000	0.000	0.000
Angle collision	0.467	1.412	0.271	2.101	3.512
Sideswipe, same direction	0.000	0.000	0.169	1.313	1.313
Sideswipe, opposite direction	0.000	0.000	0.000	0.000	0.000
Other multiple-vehicle collision	0.067	0.202	0.000	0.000	0.202

Worksheet 1E -- Single-Vehicle Collisions by Severity Level for Urban and Suburban Roadway Segments									
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)
Crash Severity Level	**SPF Coefficients**		**Overdispersion Parameter, k**	**Initial N_{brsv}**	**Proportion of Total Crashes**	**Adjusted N_{brsv}**	**Combined CMFs**	**Calibration Factor, Cr**	**Predicted N_{brsv}**
	from Table 12-5		from Table 12-5	from Equation 12-13		$(4)_{TOTAL}*(5)$	(6) from Worksheet 1B		(6)*(7)*(8)
	a	b							
Total	-5.05	0.47	0.86	1.077	1.000	1.077	2.18	1.00	2.346
Fatal and Injury (FI)	-8.71	0.66	0.28	0.182	$(4)_{FI}/((4)_{FI}+(4)_{PDO})$ 0.169	0.182	2.18	1.00	0.397
Property Damage Only (PDO)	-5.04	0.45	1.06	0.893	$(5)_{TOTAL}-(5)_{FI}$ 0.831	0.895	2.18	1.00	1.949

Worksheet 1F -- Single-Vehicle Collisions by Collision Type for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
Collision Type	**Proportion of Collision Type$_{(FI)}$**	**Predicted $N_{brsv\ (FI)}$ (crashes/year)**	**Proportion of Collision Type $_{(PDO)}$**	**Predicted $N_{brsv\ (PDO)}$ (crashes/year)**	**Predicted $N_{brsv\ (TOTAL)}$ (crashes/year)**
	from Table 12-6	$(9)_{FI}$ from Worksheet 1E	from Table 12-6	$(9)_{PDO}$ from Worksheet 1E	$(9)_{TOTAL}$ from Worksheet 1E
Total	1.000	0.397	1.000	1.949	2.346
		$(2)*(3)_{FI}$		$(4)*(5)_{PDO}$	(3)+(5)
Collision with animal	0.000	0.000	0.231	0.450	0.450
Collision with fixed object	0.333	0.132	0.385	0.750	0.882
Collision with other object	0.667	0.265	0.154	0.300	0.565
Other single-vehicle collision	0.000	0.000	0.231	0.450	0.450

Worksheet 1G -- Multiple-Vehicle Driveway-Related Collisions by Driveway Type for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
Driveway Type	Number of driveways, n_j	Crashes per driveway per year, N_j	Coefficient for traffic adjustment, t	Initial N_{brdwy}	Overdispersion parameter, k
		from Table 12-7	from Table 12-7	Equation 12-16 $n_j * N_j * (AADT/15,000)^t$	from Table 12-7
Major commercial	5	0.033	1.106	0.227	--
Minor commercial	10	0.011	1.106	0.151	
Major industrial/institutional	0	0.036	1.106	0.000	
Minor industrial/institutional	0	0.005	1.106	0.000	
Major residential	0	0.018	1.106	0.000	
Minor residential	14	0.003	1.106	0.058	
Other	0	0.005	1.106	0.000	
Total	--	--	--	0.436	1.39

Worksheet 1H -- Multiple-Vehicle Driveway-Related Collisions by Severity Level for Urban and Suburban Roadway Segments						
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Crash Severity Level	Initial N_{brdwy}	Proportion of total crashes (f_{dwy})	Adjusted N_{brdwy}	Combined CMFs	Calibration factor, C_r	Predicted N_{brdwy}
	$(5)_{TOTAL}$ from Worksheet 1G	from Table 12-7	$(2)_{TOTAL}$ * (3)	(6) from Worksheet 1B		(4)*(5)*(6)
Total	0.436	1.000	0.436	2.18	1.00	0.949
Fatal and injury (FI)	--	0.284	0.124	2.18	1.00	0.269
Property damage only (PDO)	--	0.716	0.312	2.18	1.00	0.679

Worksheet 1I -- Vehicle-Pedestrian Collisions for Urban and Suburban Roadway Segments							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Crash Severity Level	Predicted N_{brmv}	Predicted N_{brsv}	Predicted N_{brdwy}	Predicted N_{br}	f_{pedr}	Calibration factor, C_r	Predicted N_{pedr}
	(9) from Worksheet 1C	(9) from Worksheet 1E	(7) from Worksheet 1H	(2)+(3)+(4)	from Table 12-8		(5)*(6)*(7)
Total	10.771	2.346	0.949	14.066	0.067	1.00	0.942
Fatal and injury (FI)	--	--	--	--	--	1.00	0.942

Worksheet 1J -- Vehicle-Bicycle Collisions for Urban and Suburban Roadway Segments							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Crash Severity Level	Predicted N_{brmv}	Predicted N_{brsv}	Predicted N_{brdwy}	Predicted N_{br}	f_{biker}	Calibration factor, C_r	Predicted N_{biker}
	(9) from Worksheet 1C	(9) from Worksheet 1E	(7) from Worksheet 1H	(2)+(3)+(4)	from Table 12-9		(5)*(6)*(7)
Total	10.771	2.346	0.949	14.066	0.013	1.00	0.183
Fatal and injury (FI)	--	--	--	--	--	1.00	0.183

Worksheet 1K -- Crash Severity Distribution for Urban and Suburban Roadway Segments			
(1)	(2)	(3)	(4)
Collision type	**Fatal and injury (FI)**	**Property damage only (PDO)**	**Total**
	(3) from Worksheet 1D and 1F; (7) from Worksheet 1H; and (8) from Worksheet 1I and 1J	(5) from Worksheet 1D and 1F; and (7) from Worksheet 1H	(6) from Worksheet 1D and 1F; (7) from Worksheet 1H; and (8) from Worksheet 1I and 1J
MULTIPLE-VEHICLE			
Rear-end collisions (from Worksheet 1D)	1.412	4.333	5.744
Head-on collisions (from Worksheet 1D)	0.000	0.000	0.000
Angle collisions (from Worksheet 1D)	1.412	2.101	3.512
Sideswipe, same direction (from Worksheet 1D)	0.000	1.313	1.313
Sideswipe, opposite direction (from Worksheet 1D)	0.000	0.000	0.000
Driveway-related collisions (from Worksheet 1H)	0.269	0.679	0.949
Other multiple-vehicle collision (from Worksheet 1D)	0.202	0.000	0.202
Subtotal	3.294	8.426	11.720
SINGLE-VEHICLE			
Collision with animal (from Worksheet 1F)	0.000	0.450	0.450
Collision with fixed object (from Worksheet 1F)	0.132	0.750	0.882
Collision with other object (from Worksheet 1F)	0.265	0.300	0.565
Other single-vehicle collision (from Worksheet 1F)	0.000	0.450	0.450
Collision with pedestrian (from Worksheet 1I)	0.942	0.000	0.942
Collision with bicycle (from Worksheet 1J)	0.183	0.000	0.183
Subtotal	1.523	1.949	3.472
Total	4.817	10.375	15.192

Worksheet 1L -- Summary Results for Urban and Suburban Roadway Segments			
(1)	(2)	(3)	(4)
Crash Severity Level	**Predicted average crash frequency, $N_{predicted\ rs}$ (crashes/year)**	**Roadway segment length, L (mi)**	**Crash rate (crashes/mi/year)**
	(Total) from Worksheet 1K		(2) / (3)
Total	15.2	1.60	9.5
Fatal and injury (FI)	4.8	1.60	3.0
Property damage only (PDO)	10.4	1.60	6.5

Worksheet 3A -- Predicted Crashes by Severity and Site Type and Observed Crashes Using the Site-Specific EB Method for Urban and Suburban Arterials

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Collision type / Site type	Predicted average crash frequency (crashes/year)			Observed crashes, $N_{observed}$ (crashes/year)	Overdispersion Parameter, k	Weighted adjustment, w	Expected average crash frequency, $N_{expected}$
	$N_{predicted}$ (TOTAL)	$N_{predicted}$ (FI)	$N_{predicted}$ (PDO)			Equation A-5 from Part C Appendix	Equation A-4 from Part C Appendix
ROADWAY SEGMENTS							
Multiple-vehicle nondriveway							
Segment 1	10.771	3.025	7.746	24.67	1.320	0.066	23.754
Segment 2	0.000	0.000	0.000		0.840	1.000	0.000
Segment 3						1.000	0.000
Segment 4						1.000	0.000
Single-vehicle							
Segment 1	2.346	0.397	1.949	5.33	0.860	0.331	4.343
Segment 2	0.003	0.003	0.000		0.810	0.997	0.003
Segment 3						1.000	0.000
Segment 4						1.000	0.000
Multiple-vehicle driveway-related							
Segment 1	0.949	0.269	0.679	0.00	1.390	0.431	0.409
Segment 2	0.000	0.000	0.000		0.810	1.000	0.000
Segment 3						1.000	0.000
Segment 4						1.000	0.000
INTERSECTIONS							
Multiple-vehicle							
Intersection 1	0.000	0.000	0.000		0.800	1.000	0.000
Intersection 2	0.000	0.000	0.000		0.390	1.000	0.000
Intersection 3						1.000	0.000
Intersection 4						1.000	0.000
Single-vehicle							
Intersection 1	0.001	0.000	0.000		1.140	0.999	0.001
Intersection 2	0.000	0.000	0.000		0.360	1.000	0.000
Intersection 3						1.000	0.000
Intersection 4						1.000	0.000
COMBINED (sum of column)	14.071	3.695	10.376	30	--	--	28.511 per year

Worksheet 3B -- Predicted Pedestrian and Bicycle Crashes for Urban and Suburban Arterials

(1) Site Type	(2) N_{ped}	(3) N_{bike}	
ROADWAY SEGMENTS			
Segment 1	0.942	0.183	
Segment 2	0.000	0.000	
Segment 3			
Segment 4			
INTERSECTIONS			
Intersection 1	0.000	0.000	
Intersection 2	0.013	0.000	
Intersection 3			
Intersection 4			
COMBINED (sum of column)	0.955	0.183	per year

Worksheet 3C -- Site-Specific EB Method Summary Results for Urban and Suburban Arterials

(1)	(2)	(3)	(4)	(5)	(6)
Crash severity level	**$N_{predicted}$**	**N_{ped}**	**N_{bike}**	$N_{expected (VEHICLE)}$	$N_{expected}$
Total	$(2)_{COMB}$ from Worksheet 3A	$(2)_{COMB}$ from Worksheet 3B	$(3)_{COMB}$ from Worksheet 3B	$(8)_{COMB}$ Worksheet 3A	(3)+(4)+(5)
	14.1	1.0	0.2	28.5	29.6
Fatal and injury (FI)	$(3)_{COMB}$ from Worksheet 3A	$(2)_{COMB}$ from Worksheet 3B	$(3)_{COMB}$ from Worksheet 3B	$(5)_{TOTAL} * (2)_{FI} / (2)_{TOTAL}$	(3)+(4)+(5)
	3.7	1.0	0.2	7.5	8.6
Property damage only (PDO)	$(4)_{COMB}$ from Worksheet 3A	--	--	$(5)_{TOTAL} * (2)_{PDO} / (2)_{TOTAL}$	(3)+(4)+(5)
	10.4	0.0	0.0	21.0	21.0

Worksheet 3A -- Predicted Crashes by Severity and Crash Type and Observed Crashes Using the Site-Specific EB Method for Urban and Suburban Arterials

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(8)
Collision type / Site type	**Predicted average crash frequency (crashes/year)**			**Observed crashes,** $N_{observed}$ (crashes/year)	**Overdispersion Parameter, k**	**Weighted adjustment, w**	**Expected average crash frequency, $N_{expected}$**	**Expected average crash frequency, Adjusted**
	$N_{predicted}$ (TOTAL)	$N_{predicted}$ (FI)	$N_{predicted}$ (PDO)			Equation A-5 from Part C Appendix	Equation A-4 from Part C Appendix	
MULTIPLE VEHICLES								
Rear End	5.74	1.41	4.33	13.33	1.32	0.117	12.449	13.65
Head On	0.00	0.00	0.00	0.00	1.32	1.000	0.000	0.00
Angle	3.51	1.41	2.10	7.67	1.32	0.177	6.930	7.60
Sideswipe - Same Direction	1.31	0.00	1.31	3.33	1.32	0.366	2.594	2.84
Sideswipe - Opposite Direction	0.00	0.00	0.00	0.00	1.32	1.000	0.000	0.00
Driveway-related	0.95	0.27	0.68	0.00	1.39	0.431	0.409	0.45
Other multiple-vehicle	0.20	0.20	0.00	0.33	1.32	0.790	0.229	0.25
SINGLE VEHICLES								
Collision with animal	0.45	0.00	0.45	1.00	0.86	0.721	0.603	0.66
Collision with fixed object	0.88	0.13	0.75	2.00	0.86	0.569	1.364	1.50
Collision with other object	0.56	0.26	0.30	1.33	0.86	0.673	0.816	0.89
Other single-vehicle collision	0.45	0.00	0.45	1.00	0.86	0.721	0.603	0.66
Total	14.07	3.69	10.37				25.998	28.51

Worksheet 1A -- General Information and Input Data for Urban and Suburban Roadway Segments			
General Information		**Location Information**	
Analyst	TOPS Lab	Roadway	Williamson Street
Agency or Company	TOPS	Roadway Section	S. Blount St. to S. Baldwin St.
Date Performed	01/06/13	Jurisdiction	Madison, WI
		Analysis Year	

Input Data		**Base Conditions**	**Site Conditions**
Roadway type (2U, 3T, 4U, 4D, ST)		--	4U
Length of segment, L (mi)		--	0.7
AADT (veh/day)	$AADT_{MAX}$ = 40,100 (veh/day)	--	21,000
Type of on-street parking (none/parallel/angle)		None	Parallel (Comm/Ind)
Proportion of curb length with on-street parking		--	0.66
Median width (ft) - for divided only		15	Not Present
Lighting (present / not present)		Not Present	Present
Auto speed enforcement (present / not present)		Not Present	Not Present
Major commercial driveways (number)		--	4
Minor commercial driveways (number)		--	21
Major industrial / institutional driveways (number)		--	0
Minor industrial / institutional driveways (number)		--	0
Major residential driveways (number)		--	0
Minor residential driveways (number)		--	32
Other driveways (number)		--	0
Speed Category		--	Posted Speed 30 mph or Lower
Roadside fixed object density (fixed objects / mi)		0	344
Offset to roadside fixed objects (ft) [If greater than 30 or Not Present, input 30]		30	12
Calibration Factor, Cr		1.00	1.00

Worksheet 1B -- Crash Modification Factors for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
CMF for On-Street Parking	CMF for Roadside Fixed Objects	CMF for Median Width	CMF for Lighting	CMF for Automated Speed Enforcement	Combined CMF
CMF 1r	*CMF 2r*	*CMF 3r*	*CMF 4r*	*CMF 5r*	*CMF comb*
from Equation 12-32	from Equation 12-33	from Table 12-22	from Equation 12-34	from Section 12.7.1	(1)*(2)*(3)*(4)*(5)
1.47	1.95	1.00	0.92	1.00	2.63

Worksheet 1C -- Multiple-Vehicle Nondriveway Collisions by Severity Level for Urban and Suburban Roadway Segments									
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)
Crash Severity Level	**SPF Coefficients**		**Overdispersion Parameter, k**	**Initial N_{brmv}**	**Proportion of Total Crashes**	**Adjusted N_{brmv}**	**Combined CMFs**	**Calibration Factor, Cr**	**Predicted N_{brmv}**
	from Table 12-3		from Table 12-3	from Equation 12-10		$(4)_{TOTAL}$*(5)	(6) from Worksheet 1B		(6)*(7)*(8)
	a	b							
Total	-11.63	1.33	1.01	3.490	1.000	3.490	2.63	1.00	9.162
Fatal and Injury (FI)	-12.08	1.25	0.99	1.004	$(4)_{FI}/((4)_{FI}+(4)_{PDO})$ 0.301	1.050	2.63	1.00	2.755
Property Damage Only (PDO)	-12.53	1.38	1.08	2.334	$(5)_{TOTAL}-(5)_{FI}$ 0.699	2.440	2.63	1.00	6.407

Worksheet 1D -- Multiple-Vehicle Nondriveway Collisions by Collision Type for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
Collision Type	**Proportion of Collision Type$_{(FI)}$**	**Predicted N $_{brmv\ (FI)}$ (crashes/year)**	**Proportion of Collision Type $_{(PDO)}$**	**Predicted N $_{brmv\ (PDO)}$ (crashes/year)**	**Predicted N $_{brmv\ (TOTAL)}$ (crashes/year)**
	from Table 12-4	(9)$_{FI}$ from Worksheet 1C	from Table 12-4	(9)$_{PDO}$ from Worksheet 1C	(9)$_{TOTAL}$ from Worksheet 1C
Total	1.000	2.755	1.000	6.407	9.162
		(2)*(3)$_{FI}$		(4)*(5)$_{PDO}$	(3)+(5)
Rear-end collision	0.909	2.505	0.510	3.269	5.774
Head-on collision	0.000	0.000	0.000	0.000	0.000
Angle collision	0.045	0.125	0.245	1.569	1.694
Sideswipe, same direction	0.045	0.125	0.184	1.177	1.302
Sideswipe, opposite direction	0.000	0.000	0.020	0.131	0.131
Other multiple-vehicle collision	0.000	0.000	0.041	0.262	0.262

Worksheet 1E -- Single-Vehicle Collisions by Severity Level for Urban and Suburban Roadway Segments									
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)
Crash Severity Level	**SPF Coefficients**		**Overdispersion Parameter, k**	**Initial N$_{brsv}$**	**Proportion of Total Crashes**	**Adjusted N$_{brsv}$**	**Combined CMFs**	**Calibration Factor, Cr**	**Predicted N$_{brsv}$**
	from Table 12-5		from Table 12-5	from Equation 12-13		(4)$_{TOTAL}$*(5)	(6) from Worksheet 1B		(6)*(7)*(8)
	a	b							
Total	-7.99	0.81	0.91	0.752	1.000	0.752	2.63	1.00	1.974
Fatal and Injury (FI)	-7.37	0.61	0.54	0.191	(4)$_{FI}$/((4)$_{FI}$+(4)$_{PDO}$) 0.239	0.180	2.63	1.00	0.471
Property Damage Only (PDO)	-8.50	0.84	0.97	0.608	(5)$_{TOTAL}$-(5)$_{FI}$ 0.761	0.572	2.63	1.00	1.502

Worksheet 1F -- Single-Vehicle Collisions by Collision Type for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
Collision Type	**Proportion of Collision Type$_{(FI)}$**	**Predicted N $_{brsv\ (FI)}$ (crashes/year)**	**Proportion of Collision Type $_{(PDO)}$**	**Predicted N $_{brsv\ (PDO)}$ (crashes/year)**	**Predicted N $_{brsv\ (TOTAL)}$ (crashes/year)**
	from Table 12-6	(9)$_{FI}$ from Worksheet 1E	from Table 12-6	(9)$_{PDO}$ from Worksheet 1E	(9)$_{TOTAL}$ from Worksheet 1E
Total	1.000	0.471	1.000	1.502	1.974
		(2)*(3)$_{FI}$		(4)*(5)$_{PDO}$	(3)+(5)
Collision with animal	0.000	0.000	0.000	0.000	0.000
Collision with fixed object	1.000	0.471	0.333	0.501	0.972
Collision with other object	0.000	0.000	0.333	0.501	0.501
Other single-vehicle collision	0.000	0.000	0.333	0.501	0.501

Worksheet 1G -- Multiple-Vehicle Driveway-Related Collisions by Driveway Type for Urban and Suburban Roadway Segments

(1)	(2)	(3)	(4)	(5)	(6)
Driveway Type	**Number of driveways, n_j**	**Crashes per driveway per year, N_j**	**Coefficient for traffic adjustment, t**	**Initial N_{brdwy}**	**Overdispersion parameter, k**
		from Table 12-7	from Table 12-7	Equation 12-16 $n_j * N_j * (AADT/15,000)^t$	from Table 12-7
Major commercial	4	0.182	1.172	1.080	--
Minor commercial	21	0.058	1.172	1.807	
Major industrial/institutional	0	0.198	1.172	0.000	
Minor industrial/institutional	0	0.026	1.172	0.000	
Major residential	0	0.096	1.172	0.000	
Minor residential	32	0.018	1.172	0.854	
Other	0	0.029	1.172	0.000	
Total	--	--	--	3.741	0.81

Worksheet 1H -- Multiple-Vehicle Driveway-Related Collisions by Severity Level for Urban and Suburban Roadway Segments

(1)	(2)	(3)	(4)	(5)	(6)	(7)
Crash Severity Level	**Initial N_{brdwy}**	**Proportion of total crashes (f_{dwy})**	**Adjusted N_{brdwy}**	**Combined CMFs**	**Calibration factor, C_r**	**Predicted N_{brdwy}**
	$(5)_{TOTAL}$ from Worksheet 1G	from Table 12-7	$(2)_{TOTAL}$ * (3)	(6) from Worksheet 1B		(4)*(5)*(6)
Total	3.741	1.000	3.741	2.63	1.00	9.822
Fatal and injury (FI)	--	0.342	1.279	2.63	1.00	3.359
Property damage only (PDO)	--	0.658	2.462	2.63	1.00	6.463

Worksheet 1I -- Vehicle-Pedestrian Collisions for Urban and Suburban Roadway Segments

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Crash Severity Level	**Predicted N_{brmv}**	**Predicted N_{brsv}**	**Predicted N_{brdwy}**	**Predicted N_{br}**	**f_{pedr}**	**Calibration factor, C_r**	**Predicted N_{pedr}**
	(9) from Worksheet 1C	(9) from Worksheet 1E	(7) from Worksheet 1H	(2)+(3)+(4)	from Table 12-8		(5)*(6)*(7)
Total	9.162	1.974	9.822	20.959	0.022	1.00	0.461
Fatal and injury (FI)	--	--	--	--	--	1.00	0.461

Worksheet 1J -- Vehicle-Bicycle Collisions for Urban and Suburban Roadway Segments

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Crash Severity Level	**Predicted N_{brmv}**	**Predicted N_{brsv}**	**Predicted N_{brdwy}**	**Predicted N_{br}**	**f_{biker}**	**Calibration factor, C_r**	**Predicted N_{biker}**
	(9) from Worksheet 1C	(9) from Worksheet 1E	(7) from Worksheet 1H	(2)+(3)+(4)	from Table 12-9		(5)*(6)*(7)
Total	9.162	1.974	9.822	20.959	0.011	1.00	0.231
Fatal and injury (FI)	--	--	--	--	--	1.00	0.231

Worksheet 1K -- Crash Severity Distribution for Urban and Suburban Roadway Segments			
(1)	(2)	(3)	(4)
Collision type	**Fatal and injury (FI)**	**Property damage only (PDO)**	**Total**
	(3) from Worksheet 1D and 1F; (7) from Worksheet 1H; and (8) from Worksheet 1I and 1J	(5) from Worksheet 1D and 1F; and (7) from Worksheet 1H	(6) from Worksheet 1D and 1F; (7) from Worksheet 1H; and (8) from Worksheet 1I and 1J
MULTIPLE-VEHICLE			
Rear-end collisions (from Worksheet 1D)	2.505	3.269	5.774
Head-on collisions (from Worksheet 1D)	0.000	0.000	0.000
Angle collisions (from Worksheet 1D)	0.125	1.569	1.694
Sideswipe, same direction (from Worksheet 1D)	0.125	1.177	1.302
Sideswipe, opposite direction (from Worksheet 1D)	0.000	0.131	0.131
Driveway-related collisions (from Worksheet 1H)	3.359	6.463	9.822
Other multiple-vehicle collision (from Worksheet 1D)	0.000	0.262	0.262
Subtotal	6.115	12.870	18.985
SINGLE-VEHICLE			
Collision with animal (from Worksheet 1F)	0.000	0.000	0.000
Collision with fixed object (from Worksheet 1F)	0.471	0.501	0.972
Collision with other object (from Worksheet 1F)	0.000	0.501	0.501
Other single-vehicle collision (from Worksheet 1F)	0.000	0.501	0.501
Collision with pedestrian (from Worksheet 1I)	0.461	0.000	0.461
Collision with bicycle (from Worksheet 1J)	0.231	0.000	0.231
Subtotal	1.163	1.502	2.665
Total	7.278	14.372	21.650

Worksheet 1L -- Summary Results for Urban and Suburban Roadway Segments			
(1)	(2)	(3)	(4)
Crash Severity Level	**Predicted average crash frequency, $N_{predicted\ rs}$ (crashes/year)**	**Roadway segment length, L (mi)**	**Crash rate (crashes/mi/year)**
	(Total) from Worksheet 1K		(2) / (3)
Total	21.7	0.70	30.9
Fatal and injury (FI)	7.3	0.70	10.4
Property damage only (PDO)	14.4	0.70	20.5

Worksheet 3A -- Predicted Crashes by Severity and Site Type and Observed Crashes Using the Site-Specific EB Method for Urban and Suburban Arterials								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
Collision type / Site type	**Predicted average crash frequency (crashes/year)**			**Observed crashes,** $N_{observed}$ (crashes/year)	**Overdispersion Parameter, k**	**Weighted adjustment, w**	**Expected average crash frequency,** $N_{expected}$	
	$N_{predicted}$ (TOTAL)	$N_{predicted}$ (FI)	$N_{predicted}$ (PDO)			Equation A-5 from Part C Appendix	Equation A-4 from Part C Appendix	
ROADWAY SEGMENTS								
Multiple-vehicle nondriveway								
Segment 1	9.162	2.755	6.407	23.65	1.010	0.098	22.233	
Segment 2	0.000	0.000	0.000		0.840	1.000	0.000	
Segment 3						1.000	0.000	
Segment 4						1.000	0.000	
Single-vehicle								
Segment 1	1.974	0.471	1.502	1.33	0.910	0.358	1.562	
Segment 2	0.003	0.003	0.000		0.810	0.997	0.003	
Segment 3						1.000	0.000	
Segment 4						1.000	0.000	
Multiple-vehicle driveway-related								
Segment 1	9.822	3.359	6.463	0.00	0.810	0.112	1.097	
Segment 2	0.000	0.000	0.000		0.810	1.000	0.000	
Segment 3						1.000	0.000	
Segment 4						1.000	0.000	
INTERSECTIONS								
Multiple-vehicle								
Intersection 1	0.000	0.000	0.000		0.800	1.000	0.000	
Intersection 2	0.000	0.000	0.000		0.390	1.000	0.000	
Intersection 3						1.000	0.000	
Intersection 4						1.000	0.000	
Single-vehicle								
Intersection 1	0.001	0.000	0.000		1.140	0.999	0.001	
Intersection 2	0.000	0.000	0.000		0.360	1.000	0.000	
Intersection 3						1.000	0.000	
Intersection 4						1.000	0.000	
COMBINED (sum of column)	20.963	6.590	14.373	25	--	--	24.895	per year

Worksheet 3B -- Predicted Pedestrian and Bicycle Crashes for Urban and Suburban Arterials

(1) Site Type	(2) N_{ped}	(3) N_{bike}	
ROADWAY SEGMENTS			
Segment 1	0.461	0.231	
Segment 2	0.000	0.000	
Segment 3			
Segment 4			
INTERSECTIONS			
Intersection 1	0.000	0.000	
Intersection 2	0.013	0.000	
Intersection 3			
Intersection 4			
COMBINED (sum of column)	0.474	0.231	per year

Worksheet 3C -- Site-Specific EB Method Summary Results for Urban and Suburban Arterials

(1)	(2)	(3)	(4)	(5)	(6)
Crash severity level	**$N_{predicted}$**	**N_{ped}**	**N_{bike}**	$N_{expected\ (VEHICLE)}$	$N_{expected}$
Total	$(2)_{COMB}$ from Worksheet 3A	$(2)_{COMB}$ from Worksheet 3B	$(3)_{COMB}$ from Worksheet 3B	$(8)_{COMB}$ Worksheet 3A	(3)+(4)+(5)
	21.0	0.5	0.2	24.9	25.6
Fatal and injury (FI)	$(3)_{COMB}$ from Worksheet 3A	$(2)_{COMB}$ from Worksheet 3B	$(3)_{COMB}$ from Worksheet 3B	$(5)_{TOTAL}$ * $(2)_{FI}$ / $(2)_{TOTAL}$	(3)+(4)+(5)
	6.6	0.5	0.2	7.8	8.5
Property damage only (PDO)	$(4)_{COMB}$ from Worksheet 3A	--	--	$(5)_{TOTAL}$ * $(2)_{PDO}$ / $(2)_{TOTAL}$	(3)+(4)+(5)
	14.4	0.0	0.0	17.1	17.1

Worksheet 3A -- Predicted Crashes by Severity and Crash Type and Observed Crashes Using the Site-Specific EB Method for Urban and Suburban Arterials

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(8)
Collision type / Site type	**Predicted average crash frequency (crashes/year)**			**Observed crashes,** $N_{observed}$ (crashes/year)	**Overdispersion Parameter, k**	**Weighted adjustment, w**	**Expected average crash frequency,** $N_{expected}$	**Expected average crash frequency, Adjusted**
	$N_{predicted}$ (TOTAL)	$N_{predicted}$ (FI)	$N_{predicted}$ (PDO)			Equation A-5 from Part C Appendix	Equation A-4 from Part C Appendix	
MULTIPLE VEHICLES								
Rear End	5.77	2.50	3.27	14.99	1.01	0.146	13.638	14.91
Head On	0.00	0.00	0.00	0.00	1.01	1.000	0.000	0.00
Angle	1.69	0.13	1.57	4.33	1.01	0.369	3.357	3.67
Sideswipe - Same Direction	1.30	0.13	1.18	3.33	1.01	0.432	2.454	2.68
Sideswipe - Opposite Direction	0.13	0.00	0.13	0.33	1.01	0.883	0.154	0.17
Driveway-related	9.82	3.36	6.46	0.00	0.81	0.112	1.097	1.20
Other multiple-vehicle	0.26	0.00	0.26	0.67	1.01	0.791	0.346	0.38
SINGLE VEHICLES								
Collision with animal	0.00	0.00	0.00	0.00	0.91	1.000	0.000	0.00
Collision with fixed object	0.97	0.47	0.50	0.67	0.91	0.531	0.828	0.91
Collision with other object	0.50	0.00	0.50	0.33	0.91	0.687	0.448	0.49
Other single-vehicle collision	0.50	0.00	0.50	0.33	0.91	0.687	0.448	0.49
Total	20.96	6.59	14.37				22.772	24.90

Worksheet 1A -- General Information and Input Data for Urban and Suburban Roadway Segments

General Information		Location Information	
Analyst	TOPS Lab	Roadway	Marshal Avenue
Agency or Company	TOPS	Roadway Section	Mississippi River Bridge and Cretin Ave.
Date Performed	01/06/13	Jurisdiction	St. Paul, MN
		Analysis Year	

Input Data		Base Conditions	Site Conditions
Roadway type (2U, 3T, 4U, 4D, ST)		--	4U
Length of segment, L (mi)		--	0.39
AADT (veh/day)	$AADT_{MAX}$ = 40,100 (veh/day)	--	18,000
Type of on-street parking (none/parallel/angle)		None	None
Proportion of curb length with on-street parking		--	0.66
Median width (ft) - for divided only		15	Not Present
Lighting (present / not present)		Not Present	Not Present
Auto speed enforcement (present / not present)		Not Present	Not Present
Major commercial driveways (number)		--	0
Minor commercial driveways (number)		--	0
Major industrial / institutional driveways (number)		--	0
Minor industrial / institutional driveways (number)		--	0
Major residential driveways (number)		--	3
Minor residential driveways (number)		--	0
Other driveways (number)		--	0
Speed Category		--	Posted Speed Greater than 30 mph
Roadside fixed object density (fixed objects / mi)		0	351
Offset to roadside fixed objects (ft) [If greater than 30 or Not Present, input 30]		30	18
Calibration Factor, Cr		1.00	1.00

Worksheet 1B -- Crash Modification Factors for Urban and Suburban Roadway Segments

(1)	(2)	(3)	(4)	(5)	(6)
CMF for On-Street Parking	CMF for Roadside Fixed Objects	CMF for Median Width	CMF for Lighting	CMF for Automated Speed Enforcement	Combined CMF
CMF 1r	*CMF 2r*	*CMF 3r*	*CMF 4r*	*CMF 5r*	*CMF comb*
from Equation 12-32	from Equation 12-33	from Table 12-22	from Equation 12-34	from Section 12.7.1	(1)*(2)*(3)*(4)*(5)
1.00	1.75	1.00	1.00	1.00	1.75

Worksheet 1C -- Multiple-Vehicle Nondriveway Collisions by Severity Level for Urban and Suburban Roadway Segments

(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)
Crash Severity Level	**SPF Coefficients**		**Overdispersion Parameter, k**	**Initial N_{brmv}**	**Proportion of Total Crashes**	**Adjusted N_{brmv}**	**Combined CMFs**	**Calibration Factor, Cr**	**Predicted N_{brmv}**
	from Table 12-3		from Table 12-3	from Equation 12-10		$(4)_{TOTAL}$*(5)	(6) from Worksheet 1B		(6)*(7)*(8)
	a	b							
Total	-11.63	1.33	1.01	1.584	1.000	1.584	1.75	1.00	2.769
Fatal and Injury (FI)	-12.08	1.25	0.99	0.461	$(4)_{FI}/((4)_{FI}+(4)_{PDO})$ 0.305	0.483	1.75	1.00	0.844
Property Damage Only (PDO)	-12.53	1.38	1.08	1.051	$(5)_{TOTAL}-(5)_{FI}$ 0.695	1.101	1.75	1.00	1.924

Worksheet 1D -- Multiple-Vehicle Nondriveway Collisions by Collision Type for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
Collision Type	**Proportion of Collision Type$_{(FI)}$**	**Predicted $N_{brmv\ (FI)}$ (crashes/year)**	**Proportion of Collision Type $_{(PDO)}$**	**Predicted $N_{brmv\ (PDO)}$ (crashes/year)**	**Predicted $N_{brmv\ (TOTAL)}$ (crashes/year)**
	from Table 12-4	$(9)_{FI}$ from Worksheet 1C	from Table 12-4	$(9)_{PDO}$ from Worksheet 1C	$(9)_{TOTAL}$ from Worksheet 1C
Total	1.000	0.844	1.000	1.924	2.769
		$(2)*(3)_{FI}$		$(4)*(5)_{PDO}$	(3)+(5)
Rear-end collision	0.667	0.563	0.500	0.962	1.525
Head-on collision	0.000	0.000	0.067	0.128	0.128
Angle collision	0.000	0.000	0.367	0.706	0.706
Sideswipe, same direction	0.000	0.000	0.033	0.064	0.064
Sideswipe, opposite direction	0.000	0.000	0.000	0.000	0.000
Other multiple-vehicle collision	0.333	0.281	0.033	0.064	0.346

Worksheet 1E -- Single-Vehicle Collisions by Severity Level for Urban and Suburban Roadway Segments									
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)
Crash Severity Level	**SPF Coefficients**		**Overdispersion Parameter, k**	**Initial N_{brsv}**	**Proportion of Total Crashes**	**Adjusted N_{brsv}**	**Combined CMFs**	**Calibration Factor, Cr**	**Predicted N_{brsv}**
	from Table 12-5		from Table 12-5	from Equation 12-13		$(4)_{TOTAL}*(5)$	(6) from Worksheet 1B		(6)*(7)*(8)
	a	b							
Total	-7.99	0.81	0.91	0.370	1.000	0.370	1.75	1.00	0.646
Fatal and Injury (FI)	-7.37	0.61	0.54	0.097	$(4)_{FI}/((4)_{FI}+(4)_{PDO})$ 0.245	0.091	1.75	1.00	0.159
Property Damage Only (PDO)	-8.50	0.84	0.97	0.298	$(5)_{TOTAL}-(5)_{FI}$ 0.755	0.279	1.75	1.00	0.488

Worksheet 1F -- Single-Vehicle Collisions by Collision Type for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
Collision Type	**Proportion of Collision Type$_{(FI)}$**	**Predicted $N_{brsv\ (FI)}$ (crashes/year)**	**Proportion of Collision Type $_{(PDO)}$**	**Predicted $N_{brsv\ (PDO)}$ (crashes/year)**	**Predicted $N_{brsv\ (TOTAL)}$ (crashes/year)**
	from Table 12-6	$(9)_{FI}$ from Worksheet 1E	from Table 12-6	$(9)_{PDO}$ from Worksheet 1E	$(9)_{TOTAL}$ from Worksheet 1E
Total	1.000	0.159	1.000	0.488	0.646
		$(2)*(3)_{FI}$		$(4)*(5)_{PDO}$	(3)+(5)
Collision with animal	0.000	0.000	0.000	0.000	0.000
Collision with fixed object	1.000	0.159	0.500	0.244	0.402
Collision with other object	0.000	0.000	0.500	0.244	0.244
Other single-vehicle collision	0.000	0.000	0.000	0.000	0.000

Worksheet 1G -- Multiple-Vehicle Driveway-Related Collisions by Driveway Type for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
Driveway Type	**Number of driveways, n_j**	**Crashes per driveway per year, N_j**	**Coefficient for traffic adjustment, t**	**Initial N_{brdwy}**	**Overdispersion parameter, k**
		from Table 12-7	from Table 12-7	Equation 12-16 $n_j * N_j * (AADT/15,000)^t$	from Table 12-7
Major commercial	0	0.182	1.172	0.000	--
Minor commercial	0	0.058	1.172	0.000	
Major industrial/institutional	0	0.198	1.172	0.000	
Minor industrial/institutional	0	0.026	1.172	0.000	
Major residential	3	0.096	1.172	0.357	
Minor residential	0	0.018	1.172	0.000	
Other	0	0.029	1.172	0.000	
Total	--	--	--	0.357	0.81

Worksheet 1H -- Multiple-Vehicle Driveway-Related Collisions by Severity Level for Urban and Suburban Roadway Segments						
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Crash Severity Level	**Initial N_{brdwy}**	**Proportion of total crashes (f_{dwy})**	**Adjusted N_{brdwy}**	**Combined CMFs**	**Calibration factor, C_r**	**Predicted N_{brdwy}**
	$(5)_{TOTAL}$ from Worksheet 1G	from Table 12-7	$(2)_{TOTAL}$ * (3)	(6) from Worksheet 1B		(4)*(5)*(6)
Total	0.357	1.000	0.357	1.75	1.00	0.623
Fatal and injury (FI)	--	0.342	0.122	1.75	1.00	0.213
Property damage only (PDO)	--	0.658	0.235	1.75	1.00	0.410

Worksheet 1I -- Vehicle-Pedestrian Collisions for Urban and Suburban Roadway Segments							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Crash Severity Level	**Predicted N_{brmv}**	**Predicted N_{brsv}**	**Predicted N_{brdwy}**	**Predicted N_{br}**	**f_{pedr}**	**Calibration factor, C_r**	**Predicted N_{pedr}**
	(9) from Worksheet 1C	(9) from Worksheet 1E	(7) from Worksheet 1H	(2)+(3)+(4)	from Table 12-8		(5)*(6)*(7)
Total	2.769	0.646	0.623	4.039	0.009	1.00	0.036
Fatal and injury (FI)	--	--	--	--	--	1.00	0.036

Worksheet 1J -- Vehicle-Bicycle Collisions for Urban and Suburban Roadway Segments							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Crash Severity Level	**Predicted N_{brmv}**	**Predicted N_{brsv}**	**Predicted N_{brdwy}**	**Predicted N_{br}**	**f_{biker}**	**Calibration factor, C_r**	**Predicted N_{biker}**
	(9) from Worksheet 1C	(9) from Worksheet 1E	(7) from Worksheet 1H	(2)+(3)+(4)	from Table 12-9		(5)*(6)*(7)
Total	2.769	0.646	0.623	4.039	0.002	1.00	0.008
Fatal and injury (FI)	--	--	--	--	--	1.00	0.008

Worksheet 1K -- Crash Severity Distribution for Urban and Suburban Roadway Segments			
(1)	(2)	(3)	(4)
Collision type	**Fatal and injury (FI)**	**Property damage only (PDO)**	**Total**
	(3) from Worksheet 1D and 1F; (7) from Worksheet 1H; and (8) from Worksheet 1I and 1J	(5) from Worksheet 1D and 1F; and (7) from Worksheet 1H	(6) from Worksheet 1D and 1F; (7) from Worksheet 1H; and (8) from Worksheet 1I and 1J
MULTIPLE-VEHICLE			
Rear-end collisions (from Worksheet 1D)	0.563	0.962	1.525
Head-on collisions (from Worksheet 1D)	0.000	0.128	0.128
Angle collisions (from Worksheet 1D)	0.000	0.706	0.706
Sideswipe, same direction (from Worksheet 1D)	0.000	0.064	0.064
Sideswipe, opposite direction (from Worksheet 1D)	0.000	0.000	0.000
Driveway-related collisions (from Worksheet 1H)	0.213	0.410	0.623
Other multiple-vehicle collision (from Worksheet 1D)	0.281	0.064	0.346
Subtotal	1.058	2.335	3.392
SINGLE-VEHICLE			
Collision with animal (from Worksheet 1F)	0.000	0.000	0.000
Collision with fixed object (from Worksheet 1F)	0.159	0.244	0.402
Collision with other object (from Worksheet 1F)	0.000	0.244	0.244
Other single-vehicle collision (from Worksheet 1F)	0.000	0.000	0.000
Collision with pedestrian (from Worksheet 1I)	0.036	0.000	0.036
Collision with bicycle (from Worksheet 1J)	0.008	0.000	0.008
Subtotal	0.203	0.488	0.691
Total	1.261	2.822	4.083

Worksheet 1L -- Summary Results for Urban and Suburban Roadway Segments			
(1)	(2)	(3)	(4)
Crash Severity Level	**Predicted average crash frequency, $N_{predicted\ rs}$ (crashes/year)**	**Roadway segment length, L (mi)**	**Crash rate (crashes/mi/year)**
	(Total) from Worksheet 1K		(2) / (3)
Total	4.1	0.39	10.5
Fatal and injury (FI)	1.3	0.39	3.2
Property damage only (PDO)	2.8	0.39	7.2

Worksheet 3A -- Predicted Crashes by Severity and Site Type and Observed Crashes Using the Site-Specific EB Method for Urban and Suburban Arterials								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
Collision type / Site type	**Predicted average crash frequency (crashes/year)**			**Observed crashes,** $N_{observed}$ (crashes/year)	**Overdispersion Parameter, k**	**Weighted adjustment, w**	**Expected average crash frequency,** $N_{expected}$	
	$N_{predicted}$ (TOTAL)	$N_{predicted}$ (FI)	$N_{predicted}$ (PDO)			Equation A-5 from Part C Appendix	Equation A-4 from Part C Appendix	
ROADWAY SEGMENTS								
Multiple-vehicle nondriveway								
Segment 1	2.769	0.844	1.924	33.09	1.010	0.263	25.104	
Segment 2	0.000	0.000	0.000		0.840	1.000	0.000	
Segment 3						1.000	0.000	
Segment 4						1.000	0.000	
Single-vehicle								
Segment 1	0.646	0.159	0.488	7.02	0.910	0.630	3.006	
Segment 2	0.003	0.003	0.000		0.810	0.997	0.003	
Segment 3						1.000	0.000	
Segment 4						1.000	0.000	
Multiple-vehicle driveway-related								
Segment 1	0.623	0.213	0.410	2.01	0.810	0.664	1.087	
Segment 2	0.000	0.000	0.000		0.810	1.000	0.000	
Segment 3						1.000	0.000	
Segment 4						1.000	0.000	
INTERSECTIONS								
Multiple-vehicle								
Intersection 1	0.000	0.000	0.000		0.800	1.000	0.000	
Intersection 2	0.000	0.000	0.000		0.390	1.000	0.000	
Intersection 3						1.000	0.000	
Intersection 4						1.000	0.000	
Single-vehicle								
Intersection 1	0.001	0.000	0.000		1.140	0.999	0.001	
Intersection 2	0.000	0.000	0.000		0.360	1.000	0.000	
Intersection 3						1.000	0.000	
Intersection 4						1.000	0.000	
COMBINED (sum of column)	4.043	1.220	2.823	42	--	--	29.202	per year

Worksheet 3B -- Predicted Pedestrian and Bicycle Crashes for Urban and Suburban Arterials			
(1)	(2)	(3)	
Site Type	N_{ped}	N_{bike}	
ROADWAY SEGMENTS			
Segment 1	0.036	0.008	
Segment 2	0.000	0.000	
Segment 3			
Segment 4			
INTERSECTIONS			
Intersection 1	0.000	0.000	
Intersection 2	0.013	0.000	
Intersection 3			
Intersection 4			
COMBINED (sum of column)	0.049	0.008	per year

Worksheet 3C -- Site-Specific EB Method Summary Results for Urban and Suburban Arterials

(1)	(2)	(3)	(4)	(5)	(6)
Crash severity level	$N_{predicted}$	N_{ped}	N_{bike}	$N_{expected\ (VEHICLE)}$	$N_{expected}$
Total	$(2)_{COMB}$ from Worksheet 3A	$(2)_{COMB}$ from Worksheet 3B	$(3)_{COMB}$ from Worksheet 3B	$(8)_{COMB}$ Worksheet 3A	(3)+(4)+(5)
	4.0	0.0	0.0	29.2	29.3
Fatal and injury (FI)	$(3)_{COMB}$ from Worksheet 3A	$(2)_{COMB}$ from Worksheet 3B	$(3)_{COMB}$ from Worksheet 3B	$(5)_{TOTAL} * (2)_{FI} / (2)_{TOTAL}$	(3)+(4)+(5)
	1.2	0.0	0.0	8.8	8.9
Property damage only (PDO)	$(4)_{COMB}$ from Worksheet 3A	--	--	$(5)_{TOTAL} * (2)_{PDO} / (2)_{TOTAL}$	(3)+(4)+(5)
	2.8	0.0	0.0	20.4	20.4

Worksheet 3A -- Predicted Crashes by Severity and Crash Type and Observed Crashes Using the Site-Specific EB Method for Urban and Suburban Arterials

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(8)
Collision type / Site type	Predicted average crash frequency (crashes/year)			Observed crashes, $N_{observed}$ (crashes/year)	Overdispersion Parameter, k	Weighted adjustment, w	Expected average crash frequency, $N_{expected}$	Expected average crash frequency, Adjusted
	$N_{predicted}$ (TOTAL)	$N_{predicted}$ (FI)	$N_{predicted}$ (PDO)			Equation A-5 from Part C Appendix	Equation A-4 from Part C Appendix	
MULTIPLE VEHICLES								
Rear End	1.53	0.56	0.96	17.05	1.01	0.394	10.937	15.67
Head On	0.13	0.00	0.13	2.01	1.01	0.885	0.344	0.49
Angle	0.71	0.00	0.71	11.03	1.01	0.584	5.002	7.17
Sideswipe - Same Direction	0.06	0.00	0.06	1.00	1.01	0.939	0.121	0.17
Sideswipe - Opposite Direction	0.00	0.00	0.00	0.00	1.01	1.000	0.000	0.00
Driveway-related	0.62	0.21	0.41	2.01	0.81	0.664	1.087	1.56
Other multiple-vehicle	0.35	0.28	0.06	2.01	1.01	0.741	0.775	1.11
SINGLE VEHICLES								
Collision with animal	0.00	0.00	0.00	0.00	0.91	1.000	0.000	0.00
Collision with fixed object	0.40	0.16	0.24	4.01	0.91	0.732	1.370	1.96
Collision with other object	0.24	0.00	0.24	3.01	0.91	0.818	0.746	1.07
Other single-vehicle collision	0.00	0.00	0.00	0.00	0.91	1.000	0.000	0.00
Total	4.04	1.22	2.82				20.382	29.20

Worksheet 1A -- General Information and Input Data for Urban and Suburban Roadway Segments			
General Information		**Location Information**	
Analyst	TOPS Lab	Roadway	Franklin Avenue
Agency or Company	TOPS	Roadway Section	Mississippi River Bridge and Cedar Ave.
Date Performed	01/06/13	Jurisdiction	Minneapolis, MN
		Analysis Year	

Input Data		**Base Conditions**	**Site Conditions**
Roadway type (2U, 3T, 4U, 4D, ST)		--	4U
Length of segment, L (mi)		--	0.9
AADT (veh/day)	$AADT_{MAX}$ = 40,100 (veh/day)	--	12,500
Type of on-street parking (none/parallel/angle)		None	None
Proportion of curb length with on-street parking		--	0.66
Median width (ft) - for divided only		15	Not Present
Lighting (present / not present)		Not Present	Not Present
Auto speed enforcement (present / not present)		Not Present	Not Present
Major commercial driveways (number)		--	4
Minor commercial driveways (number)		--	7
Major industrial / institutional driveways (number)		--	0
Minor industrial / institutional driveways (number)		--	0
Major residential driveways (number)		--	0
Minor residential driveways (number)		--	0
Other driveways (number)		--	0
Speed Category		--	Posted Speed 30 mph or Lower
Roadside fixed object density (fixed objects / mi)		0	361
Offset to roadside fixed objects (ft) [If greater than 30 or Not Present, input 30]		30	3
Calibration Factor, Cr		1.00	1.00

Worksheet 1B -- Crash Modification Factors for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
CMF for On-Street Parking	CMF for Roadside Fixed Objects	CMF for Median Width	CMF for Lighting	CMF for Automated Speed Enforcement	Combined CMF
CMF 1r	*CMF 2r*	*CMF 3r*	*CMF 4r*	*CMF 5r*	*CMF comb*
from Equation 12-32	from Equation 12-33	from Table 12-22	from Equation 12-34	from Section 12.7.1	(1)*(2)*(3)*(4)*(5)
1.00	3.39	1.00	1.00	1.00	3.39

Worksheet 1C -- Multiple-Vehicle Nondriveway Collisions by Severity Level for Urban and Suburban Roadway Segments									
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)
Crash Severity Level	**SPF Coefficients**		**Overdispersion Parameter, k**	**Initial N_{brmv}**	**Proportion of Total Crashes**	**Adjusted N_{brmv}**	**Combined CMFs**	**Calibration Factor, Cr**	**Predicted N_{brmv}**
	from Table 12-3		from Table 12-3	from Equation 12-10		$(4)_{TOTAL}$*(5)	(6) from Worksheet 1B		(6)*(7)*(8)
	a	b							
Total	-11.63	1.33	1.01	2.251	1.000	2.251	3.39	1.00	7.628
Fatal and Injury (FI)	-12.08	1.25	0.99	0.675	$(4)_{FI}/((4)_{FI}+(4)_{PDO})$ 0.315	0.709	3.39	1.00	2.404
Property Damage Only (PDO)	-12.53	1.38	1.08	1.466	$(5)_{TOTAL}-(5)_{FI}$ 0.685	1.541	3.39	1.00	5.224

Worksheet 1D -- Multiple-Vehicle Nondriveway Collisions by Collision Type for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
Collision Type	**Proportion of Collision Type$_{(FI)}$**	**Predicted $N_{brmv\ (FI)}$ (crashes/year)**	**Proportion of Collision Type $_{(PDO)}$**	**Predicted $N_{brmv\ (PDO)}$ (crashes/year)**	**Predicted $N_{brmv\ (TOTAL)}$ (crashes/year)**
	from Table 12-4	$(9)_{FI}$ from Worksheet 1C	from Table 12-4	$(9)_{PDO}$ from Worksheet 1C	$(9)_{TOTAL}$ from Worksheet 1C
Total	1.000	2.404	1.000	5.224	7.628
		$(2)*(3)_{FI}$		$(4)*(5)_{PDO}$	(3)+(5)
Rear-end collision	0.800	1.923	0.214	1.119	3.042
Head-on collision	0.000	0.000	0.000	0.000	0.000
Angle collision	0.200	0.481	0.536	2.799	3.279
Sideswipe, same direction	0.000	0.000	0.036	0.187	0.187
Sideswipe, opposite direction	0.000	0.000	0.071	0.373	0.373
Other multiple-vehicle collision	0.000	0.000	0.143	0.746	0.746

Worksheet 1E -- Single-Vehicle Collisions by Severity Level for Urban and Suburban Roadway Segments									
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)
Crash Severity Level	**SPF Coefficients**		**Overdispersion Parameter, k**	**Initial N_{brsv}**	**Proportion of Total Crashes**	**Adjusted N_{brsv}**	**Combined CMFs**	**Calibration Factor, Cr**	**Predicted N_{brsv}**
	from Table 12-5		from Table 12-5	from Equation 12-13		$(4)_{TOTAL}*(5)$	(6) from Worksheet 1B		(6)*(7)*(8)
	a	b							
Total	-7.99	0.81	0.91	0.635	1.000	0.635	3.39	1.00	2.152
Fatal and Injury (FI)	-7.37	0.61	0.54	0.179	$(4)_{FI}/((4)_{FI}+(4)_{PDO})$ 0.261	0.166	3.39	1.00	0.562
Property Damage Only (PDO)	-8.50	0.84	0.97	0.506	$(5)_{TOTAL}-(5)_{FI}$ 0.739	0.469	3.39	1.00	1.590

Worksheet 1F -- Single-Vehicle Collisions by Collision Type for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
Collision Type	**Proportion of Collision Type$_{(FI)}$**	**Predicted $N_{brsv\ (FI)}$ (crashes/year)**	**Proportion of Collision Type $_{(PDO)}$**	**Predicted $N_{brsv\ (PDO)}$ (crashes/year)**	**Predicted $N_{brsv\ (TOTAL)}$ (crashes/year)**
	from Table 12-6	$(9)_{FI}$ from Worksheet 1E	from Table 12-6	$(9)_{PDO}$ from Worksheet 1E	$(9)_{TOTAL}$ from Worksheet 1E
Total	1.000	0.562	1.000	1.590	2.152
		$(2)*(3)_{FI}$		$(4)*(5)_{PDO}$	(3)+(5)
Collision with animal	0.000	0.000	0.000	0.000	0.000
Collision with fixed object	1.000	0.562	0.600	0.954	1.516
Collision with other object	0.000	0.000	0.200	0.318	0.318
Other single-vehicle collision	0.000	0.000	0.200	0.318	0.318

Worksheet 1G -- Multiple-Vehicle Driveway-Related Collisions by Driveway Type for Urban and Suburban Roadway Segments					
(1)	(2)	(3)	(4)	(5)	(6)
Driveway Type	**Number of driveways, n_j**	**Crashes per driveway per year, N_j**	**Coefficient for traffic adjustment, t**	**Initial N_{brdwy}**	**Overdispersion parameter, k**
		from Table 12-7	from Table 12-7	Equation 12-16 $n_j * N_j * (AADT/15,000)^t$	from Table 12-7
Major commercial	4	0.182	1.172	0.588	--
Minor commercial	7	0.058	1.172	0.328	
Major industrial/institutional	0	0.198	1.172	0.000	
Minor industrial/institutional	0	0.026	1.172	0.000	
Major residential	0	0.096	1.172	0.000	
Minor residential	0	0.018	1.172	0.000	
Other	0	0.029	1.172	0.000	
Total	--	--	--	0.916	0.81

Worksheet 1H -- Multiple-Vehicle Driveway-Related Collisions by Severity Level for Urban and Suburban Roadway Segments						
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Crash Severity Level	**Initial N_{brdwy}**	**Proportion of total crashes (f_{dwy})**	**Adjusted N_{brdwy}**	**Combined CMFs**	**Calibration factor, C_r**	**Predicted N_{brdwy}**
	$(5)_{TOTAL}$ from Worksheet 1G	from Table 12-7	$(2)_{TOTAL}$ * (3)	(6) from Worksheet 1B		(4)*(5)*(6)
Total	0.916	1.000	0.916	3.39	1.00	3.104
Fatal and injury (FI)	--	0.342	0.313	3.39	1.00	1.062
Property damage only (PDO)	--	0.658	0.603	3.39	1.00	2.042

Worksheet 1I -- Vehicle-Pedestrian Collisions for Urban and Suburban Roadway Segments							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Crash Severity Level	**Predicted N_{brmv}**	**Predicted N_{brsv}**	**Predicted N_{brdwy}**	**Predicted N_{br}**	**f_{pedr}**	**Calibration factor, C_r**	**Predicted N_{pedr}**
	(9) from Worksheet 1C	(9) from Worksheet 1E	(7) from Worksheet 1H	(2)+(3)+(4)	from Table 12-8		(5)*(6)*(7)
Total	7.628	2.152	3.104	12.884	0.022	1.00	0.283
Fatal and injury (FI)	--	--	--	--	--	1.00	0.283

Worksheet 1J -- Vehicle-Bicycle Collisions for Urban and Suburban Roadway Segments							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Crash Severity Level	**Predicted N_{brmv}**	**Predicted N_{brsv}**	**Predicted N_{brdwy}**	**Predicted N_{br}**	**f_{biker}**	**Calibration factor, C_r**	**Predicted N_{biker}**
	(9) from Worksheet 1C	(9) from Worksheet 1E	(7) from Worksheet 1H	(2)+(3)+(4)	from Table 12-9		(5)*(6)*(7)
Total	7.628	2.152	3.104	12.884	0.011	1.00	0.142
Fatal and injury (FI)	--	--	--	--	--	1.00	0.142

Worksheet 1K -- Crash Severity Distribution for Urban and Suburban Roadway Segments			
(1)	(2)	(3)	(4)
Collision type	**Fatal and injury (FI)**	**Property damage only (PDO)**	**Total**
	(3) from Worksheet 1D and 1F; (7) from Worksheet 1H; and (8) from Worksheet 1I and 1J	(5) from Worksheet 1D and 1F; and (7) from Worksheet 1H	(6) from Worksheet 1D and 1F; (7) from Worksheet 1H; and (8) from Worksheet 1I and 1J
MULTIPLE-VEHICLE			
Rear-end collisions (from Worksheet 1D)	1.923	1.119	3.042
Head-on collisions (from Worksheet 1D)	0.000	0.000	0.000
Angle collisions (from Worksheet 1D)	0.481	2.799	3.279
Sideswipe, same direction (from Worksheet 1D)	0.000	0.187	0.187
Sideswipe, opposite direction (from Worksheet 1D)	0.000	0.373	0.373
Driveway-related collisions (from Worksheet 1H)	1.062	2.042	3.104
Other multiple-vehicle collision (from Worksheet 1D)	0.000	0.746	0.746
Subtotal	3.465	7.267	10.732
SINGLE-VEHICLE			
Collision with animal (from Worksheet 1F)	0.000	0.000	0.000
Collision with fixed object (from Worksheet 1F)	0.562	0.954	1.516
Collision with other object (from Worksheet 1F)	0.000	0.318	0.318
Other single-vehicle collision (from Worksheet 1F)	0.000	0.318	0.318
Collision with pedestrian (from Worksheet 1I)	0.283	0.000	0.283
Collision with bicycle (from Worksheet 1J)	0.142	0.000	0.142
Subtotal	0.987	1.590	2.577
Total	4.452	8.856	13.309

Worksheet 1L -- Summary Results for Urban and Suburban Roadway Segments			
(1)	(2)	(3)	(4)
Crash Severity Level	**Predicted average crash frequency, $N_{predicted\ rs}$ (crashes/year)**	**Roadway segment length, L (mi)**	**Crash rate (crashes/mi/year)**
	(Total) from Worksheet 1K		(2) / (3)
Total	13.3	0.90	14.8
Fatal and injury (FI)	4.5	0.90	4.9
Property damage only (PDO)	8.9	0.90	9.8

Worksheet 3A -- Predicted Crashes by Severity and Site Type and Observed Crashes Using the Site-Specific EB Method for Urban and Suburban Arterials								
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	
Collision type / Site type	**Predicted average crash frequency (crashes/year)**			**Observed crashes,** $N_{observed}$ (crashes/year)	**Overdispersion Parameter, k**	**Weighted adjustment, w**	**Expected average crash frequency,** $N_{expected}$	
	$N_{predicted}$ (TOTAL)	$N_{predicted}$ (FI)	$N_{predicted}$ (PDO)			Equation A-5 from Part C Appendix	Equation A-4 from Part C Appendix	
ROADWAY SEGMENTS								
Multiple-vehicle nondriveway								
Segment 1	7.628	2.404	5.224	33.09	1.010	0.115	30.165	
Segment 2	0.000	0.000	0.000		0.840	1.000	0.000	
Segment 3						1.000	0.000	
Segment 4						1.000	0.000	
Single-vehicle								
Segment 1	2.152	0.562	1.590	6.02	0.910	0.338	4.710	
Segment 2	0.003	0.003	0.000		0.810	0.997	0.003	
Segment 3						1.000	0.000	
Segment 4						1.000	0.000	
Multiple-vehicle driveway-related								
Segment 1	3.104	1.062	2.042	0.00	0.810	0.285	0.883	
Segment 2	0.000	0.000	0.000		0.810	1.000	0.000	
Segment 3						1.000	0.000	
Segment 4						1.000	0.000	
INTERSECTIONS								
Multiple-vehicle								
Intersection 1	0.000	0.000	0.000		0.800	1.000	0.000	
Intersection 2	0.000	0.000	0.000		0.390	1.000	0.000	
Intersection 3						1.000	0.000	
Intersection 4						1.000	0.000	
Single-vehicle								
Intersection 1	0.001	0.000	0.000		1.140	0.999	0.001	
Intersection 2	0.000	0.000	0.000		0.360	1.000	0.000	
Intersection 3						1.000	0.000	
Intersection 4						1.000	0.000	
COMBINED (sum of column)	12.888	4.031	8.857	39	--	--	35.763	per year

Worksheet 3B -- Predicted Pedestrian and Bicycle Crashes for Urban and Suburban Arterials

(1)	(2)	(3)	
Site Type	**N_{ped}**	**N_{bike}**	
ROADWAY SEGMENTS			
Segment 1	0.283	0.142	
Segment 2	0.000	0.000	
Segment 3			
Segment 4			
INTERSECTIONS			
Intersection 1	0.000	0.000	
Intersection 2	0.013	0.000	
Intersection 3			
Intersection 4			
COMBINED (sum of column)	0.296	0.142	per year

Worksheet 3C -- Site-Specific EB Method Summary Results for Urban and Suburban Arterials

(1)	(2)	(3)	(4)	(5)	(6)
Crash severity level	**$N_{predicted}$**	**N_{ped}**	**N_{bike}**	$N_{expected\ (VEHICLE)}$	$N_{expected}$
Total	$(2)_{COMB}$ from Worksheet 3A	$(2)_{COMB}$ from Worksheet 3B	$(3)_{COMB}$ from Worksheet 3B	$(8)_{COMB}$ Worksheet 3A	(3)+(4)+(5)
	12.9	0.3	0.1	35.8	36.2
Fatal and injury (FI)	$(3)_{COMB}$ from Worksheet 3A	$(2)_{COMB}$ from Worksheet 3B	$(3)_{COMB}$ from Worksheet 3B	$(5)_{TOTAL}$ * $(2)_{FI}$ / $(2)_{TOTAL}$	(3)+(4)+(5)
	4.0	0.3	0.1	11.2	11.6
Property damage only (PDO)	$(4)_{COMB}$ from Worksheet 3A	--	--	$(5)_{TOTAL}$ * $(2)_{PDO}$ / $(2)_{TOTAL}$	(3)+(4)+(5)
	8.9	0.0	0.0	24.6	24.6

Worksheet 3A -- Predicted Crashes by Severity and Crash Type and Observed Crashes Using the Site-Specific EB Method for Urban and Suburban Arterials

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(8)
Collision type / Site type	**Predicted average crash frequency (crashes/year)**			**Observed crashes,** $N_{observed}$ (crashes/year)	**Overdispersion Parameter, k**	**Weighted adjustment, w**	**Expected average crash frequency,** $N_{expected}$	**Expected average crash frequency, Adjusted**
	$N_{predicted}$ (TOTAL)	$N_{predicted}$ (FI)	$N_{predicted}$ (PDO)			Equation A-5 from Part C Appendix	Equation A-4 from Part C Appendix	
MULTIPLE VEHICLES								
Rear End	3.04	1.92	1.12	10.03	1.01	0.246	8.312	10.09
Head On	0.00	0.00	0.00	0.00	1.01	1.000	0.000	0.00
Angle	3.28	0.48	2.80	16.04	1.01	0.232	13.084	15.88
Sideswipe - Same Direction	0.19	0.00	0.19	1.00	1.01	0.841	0.316	0.38
Sideswipe - Opposite Direction	0.37	0.00	0.37	2.01	1.01	0.726	0.820	1.00
Driveway-related	3.10	1.06	2.04	0.00	0.81	0.285	0.883	1.07
Other multiple-vehicle	0.75	0.00	0.75	4.01	1.01	0.570	2.149	2.61
SINGLE VEHICLES								
Collision with animal	0.00	0.00	0.00	0.00	0.91	1.000	0.000	0.00
Collision with fixed object	1.52	0.56	0.95	4.01	0.91	0.420	2.962	3.60
Collision with other object	0.32	0.00	0.32	1.00	0.91	0.776	0.472	0.57
Other single-vehicle collision	0.32	0.00	0.32	1.00	0.91	0.776	0.472	0.57
Total	12.88	4.03	8.86				29.471	35.76

Appendix B: Study Sites Summary Sheets

Complete Streets Project Evaluation Summary

Study Site Information						
Road Name	From Road	To Road	Road Type	Jurisdiction	Before Period	After Period
Excelsior Blvd.	Quentin Dr.	Monetery Dr.	Four Lane Divided	Minneapolis, MN (Hennepin County)	2.8 Years	2.2 Years
AADT (veh/day)	Road Length (miles)	Speed Limit (mph)	Area Type	Improvement Type	Parking	
20,000	0.35	35	Urban	Lane and Parking improvements etc.	Parallel (Comm/Ind)	

Study Site Description, General Information, and Safety Issues

1. This study site is located in the City of St. Louis Park; it is a minor arterial that had a 4 lane, divided cross-section.
2. The majority of the surrounding property is commercial, though there are some large apartment buildings.
3. Sidewalks were present on both sides of the road prior to and following the reconstruct.
4. Bicycle lanes are not present on this roadway.

Reconstruction Work

1. After reconstruction, the cross-section maintained 4 travel lanes that were divided by a raised median.
2. New curb and gutter was added along the median sections leading to an increase in width along one side, and a decrease along the other.
3. As a result of installing new curb and gutter, the width of the sidewalks which were maintained on both sides of the road increased.
4. Bicycle lanes were not added during the re-construct.

Results Summary

1. Overall, the results show the improvements made substantially reduced the number and severity of vehicle crashes, but not pedestrian and bike crashes.
2. Both analyses of crash types show a decrease in the number of crashes after construction with the exception of single vehicle fixed object crashes which have increased (possibly due to installation of light poles and other fixed objects during reconstruction).
3. The simple before-after analysis of crash severity shows a decrease in PDO crashes, but an increase in FI crashes; the EB analysis shows a decrease in FI crashes indicating a possible regression to the mean effect.
4. Simple before-after analysis shows bike and pedestrian crashes increased following reconstruction.

Complete Streets Project Evaluation Summary

Study Site Information

Road Name	From Road	To Road	Road Type	Jurisdiction	Before Period	After Period
Lyndale Avenue	W. 44th St.	W. 34th St.	Two Lane Undivided	Minneapolis, MN (Hennepin County)	3.4 Years	2.3 Years
AADT (veh/day)	**Road Length (miles)**	**Speed Limit (mph)**	**Area Type**	**Improvement Type**	**Parking**	
14,000	1.3	30	Urban	Pavement Markings, Lane Width Changes	Parallel (Residential)	

Study Site Description, General Information, and Safety Issues

1. Lyndale Ave. was a two-lane undivided minor arterial with parking lanes on both sides.
2. The section of road has residential areas on both sides with a number of driveways.
3. There were no bike lanes before reconstruction. Transit presence is also minimum.
4. Sidewalks are present on both sides of the road.

Reconstruction Work

1. Reconstruction work primarily consisted of pavement marking improvements to clearly show parking lanes. A raised median was also constructed on a section of the study site along with lane demarkations. No bike lanes were provided.

Results Summary

1. Overall, the results show that the improvements made led to a substantial reduction in the number and severity of vehicle and bike/pedestrian crashes.
2. Simple before-after analysis of crash types shows a decrease in the number of all crashes except sideswipe opposite direction crashes; EB analysis shows an increase in both sideswipe same direction and head-on crashes although the significance of the increase in head-on crashes is difficult to determine.
3. Both analyses of crash severity show a decrease in substantial decrease in crash severity.
4. Simple before-after analysis shows that the number of bike and pedestrian crashes has decreased following construction, possibly due to installation of a median and pavement marking improvements.

Complete Streets Project Evaluation Summary

Study Site Information						
Road Name	From Road	To Road	Road Type	Jurisdiction	Before Period	After Period
Lake Street	5th Ave. South	22nd Ave. South	Four Lane Undivided	Minneapolis, MN (Hennepin County)	3.4 Years	5.3 Years
AADT (veh/day)	Road Length (miles)	Speed Limit (mph)	Area Type	Improvement Type	Parking	
20,000	1.48	30	Urban	Pavement Markings, Delineation, Curb Extensions	Parallel (Comm/Ind)	

Study Site, Description, General Information, and Safety Issues

1. The study site is located in the City of Minneapolis; it is a minor arterial and had a 4 lane, undivided cross-section.
2. Surrounding property is primarily residential, though some businesses are present.
3. Sidewalks are present on both sides of the road.
4. There are no bicycle lanes at this location.

Reconstruction Work

1. The road was repaved in 2006; new pavement markings were installed/painted.
2. The cross-section maintained 4 lanes following the re-construct.
3. Curb extensions, parking lanes, and exclusive turn lanes were added at select points along the alignment.
4. Prior to the 2006, parking was allowed on both sides of the road. After the re-construct it is only allowed on both side in some locations; in other locations it is not allowed at all, or allowed on one side only.

Results Summary

1. Overall, the results show that the improvements made were able to reduce the number and severity of vehicle crashes, but not of bike/pedestrian crashes.
2. The numbers of head-on, angle, and driveway-related crashes are shown to have decreased, but the numbers of sideswipe, rear-end, and single-vehicle crashes are shown to have increased.
3. Both analyses show a substantial decrease in crash severity.
4. Simple before-after analysis showed an increase in the number of bike/pedestrian crashes; this could possibly be due to drivers increasing speed in response to improved pavement conditions.

Complete Streets Project Evaluation Summary

Study Site Information

Road Name	From Road	To Road	Road Type	Jurisdiction	Before Period	After Period
76th St.	Xerxes Ave. S	12th Ave. S	Four Lane Undivided	Richfield, MN	1 Years	0.7 Years
AADT (veh/day)	**Road Length (miles)**	**Speed Limit (mph)**	**Area Type**	**Improvement Type**	**Parking**	
4,000	1.9	30	Urban	Lane Reduction, Bike Lanes, Sidewalks	Parallel (Residential)	

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Complete Streets Project Evaluation Summary

Study Site Information

Road Name	From Road	To Road	Road Type	Jurisdiction	Before Period	After Period
TH 169	W. Jackson St.	W. Union St.	Four Lane Divided	St. Peter, MN	3 Years	1.2 Years
AADT (veh/day)	**Road Length (miles)**	**Speed Limit (mph)**	**Area Type**	**Improvement Type**	**Parking**	
20,000	1.6	30	Urban	TWLTL, median	None	

Study Site Description, General Information, and Safety Issues

1. The study site is located in the City of St. Peter; it is an arterial and has a 4 lane cross-section.
2. In many locations, the lanes were separated by a TWLTL.
3. Most properties in the area are residential, but there are also some small businesses.
4. Sidewalks, separated from the roadway by terrace sections, are provided on both sides of the road.
5. No bike lanes are present at this location.

Reconstruction Work

1. 4 lanes were maintained following the reconstruction in 2009-2010.
2. New median sections were implemented including raised sections, as well as wider TWLTLs.
3. No new parking was added; parking lanes are present in one section only.
4. The width of the outside lanes was increased in some cases.

Results Summary

1. Overall, analysis shows that the improvements made led to a decrease in the number and severity of crashes at this site.
2. Both simple before-after and EB analysis show a decrease in the number of angle and sideswipe-same direction crashes after reconstruction; rear-end and sideswipe-opposite directions are shown to have increased.
3. Both crash severity and the number of single vehicle crashes are shown to have decreased.
4. Simple before-after analysis shows that the number of bike and pedestrian crashes have decreased, possibly due to the installation of a median and improved pavement markings.

Complete Streets Project Evaluation Summary

Study Site Information							
Road Name	From Road	To Road	Road Type	Jurisdiction	Before Period	After Period	
Hennepin Ave.	8th St.	North Washington Ave.	One-way	Minneapolis, MN	2.1 Years	1.1 Years	
AADT (veh/day)	Road Length (miles)	Speed Limit (mph)	Area Type	Improvement Type	Parking		
0	0.5	30	Urban	One-way to Two-way conversion, Bike Lanes	Parallel (Comm/Ind)		

Study Site Description, General Information, and Safety Issues

1. The study site is located in the City of Minneapolis and was the most urban area examined; it is an arterial and was a one-way street.
2. Adjacent to the travel lanes was a two-way bicycle facility, located in the roadway, and a bus lane.
3. Surrounding property is commercial as the site falls in the central business district of Minneapolis.
4. Sidewalks were and still are present on both sides of the roadway.

Reconstruction Work

1. Following the re-construct, it was converted into a bi-directional, 4 lane, undivided roadway in which the outside lanes are wide, shared lanes for use by motorists and bicyclists.
2. Bicycle lane paths in the shared lanes were overlaid with green paint to increase conspicuity.
3. Following the re-construct, parking is no longer allowed.

Results Summary

1. Overall, analysis shows that the improvements led to a substantial reduction in both the number and severity of vehicle and bike/pedestrian crashes.
2. EB analysis could not be performed since the HSM does not include safety performance functions for one-way roads.
3. Analysis of crash types shows a reduction in the number of crashes with the exception of head-on crashes; this can be explained by the one-way to two-way conversion of the street.

Complete Streets Project Evaluation Summary

Study Site Information

Road Name	From Road	To Road	Road Type	Jurisdiction	Before Period	After Period
1st. Avenue	8th St.	North Washington Ave.	One-way	Minneapolis, MN	2.1 Years	1 Years
AADT (veh/day)	Road Length (miles)	Speed Limit (mph)	Area Type	Improvement Type	Parking	
0	0.5	30	Urban	One-way to Two-way Conversion, Bike Lanes	Parallel (Comm/Ind)	

Study Site Description, General Information, and Safety Issues

1. The study site is located in the City of Minneapolis and was the most urban area examined; it is an arterial and was a one-way street, with 3 travel lanes in addition to a parking lane on each side.
2. Surrounding property is commercial as the site falls in the central business district of Minneapolis.
3. Sidewalks were present on both sides of the roadway prior to the reconstruct, but bicycle lanes did not exist.

Reconstruction Work

1. After the reconstruction work, it was converted into a bi-directional, undivided highway with bicycle lanes on both sides.
2. In one direction of travel, the new configuration features a travel lane and a dedicated parking lane.
3. In the other direction, there are 2 travel lanes; off-peak parking is allowed in the outer lane.

Results Summary

1. Overall, analysis shows that the improvements led to a substantial reduction in both the number and severity of vehicle and bike/pedestrian crashes.
2. EB analysis could not be performed since the HSM does not include safety performance functions for one-way roads.
3. Analysis of crash types shows a reduction in the number of crashes with the exception single vehicle fixed object crashes which increased slightly following construction.
4. Crash severity analysis shows an increase in FI crashes.

Complete Streets Project Evaluation Summary

Study Site Information

Road Name	From Road	To Road	Road Type	Jurisdiction	Before Period	After Period
Williamson Street	S. Blount St.	S. Baldwin St.	Four Lane Undivided	Madison, WI	3 Years	0.9 Years
AADT (veh/day)	**Road Length (miles)**	**Speed Limit (mph)**	**Area Type**	**Improvement Type**	**Parking**	
21,000	0.7	30	Urban	Lane Width Reduction, Curb Extensions etc.	Parallel (Comm/Ind)	

Study Site Description, General Information, and Safety Issues

1. This study site is in the City of Madison, WI; it is an arterial and has a 2 lane, undivided cross-section with parking lanes on both sides of the roadway.
2. A mix of commercial and residential property is present along the street, with many small businesses.
3. Sidewalks were and still are present on both sides of the roadway; they are separated from the road via terrace sections.
4. Bike lanes were not present prior to the reconstruct.

Reconstruction Work

1. In 2011, the width of the roadway was narrowed by 4 feet, but the 2 lane, undivided cross-section was maintained.
2. The 4 lane, undivided cross-section was maintained, but parking and travel lane widths were all decreased by 1 foot.
3. The width taken away from the road was for increasing terrace width by 2 feet on each side of the road.
4. Bike lanes, the delineation for which was added during the re-construct), are only present in the study area for less than a block near Blount St.

Results Summary

1. Overall, the results show the improvements made led to a decrease in both the number and severity of vehicle and bike/pedestrian crashes.
2. The simple before-after and EB analysis of crash types show a decrease in the number of crashes following construction with the exception of sideswipe-same direction crashes and single vehicle crashes.
3. Crash severity analysis shows a decrease in FI crashes, but a slight increase in PDO crashes.
4. Bike and pedestrian crashes are shown to have decreased, but the results should be interpreted with caution due to lack of data in the after period.

Complete Streets Project Evaluation Summary

Study Site Information

Road Name	From Road	To Road	Road Type	Jurisdiction	Before Period	After Period
Marshall Ave.	MRB	Cretin Ave.	Four Lane Undivided	St. Paul, MN	1 Years	1 Years
AADT (veh/day)	**Road Length (miles)**	**Speed Limit (mph)**	**Area Type**	**Improvement Type**	**Parking**	
18,000	0.39	35	Urban	Lane Drop, Bike Lanes,	None	

Study Site Description, General Info, and Safety Issues

1. This study site is located in the City of St. Paul; it is a minor arterial and had a 4 lane, undivided cross-section.
2. The majority of the property in the area is residential.
3. Prior to the re-construct, a sidewalk was only present on the South side of the road.
4. There were no bicycle lanes prior to the reconstruction.

Countermeasures

1. Reconstruction efforts involved a combination of narrowing and widening of the roadway in addition to reallocating space for lanes; the highway remained undivided after the re-construct.
2. A bicycle lane was added in EB direction and wide shared lane for use by motorists and bicyclists was created in the WB direction; "Bicycles May Use Full Lane Signage" was added along this lane.
3. A sidewalk was added on the North side of the roadway and the sidewalk was maintained on the South side of the roadway.

Results Summary

1. Overall, it is not clear if the resulting increase in crashes is random or due to a systematic problem; crash data analyzed was only available for one year in both the before and after periods.
2. Simple before-after analysis shows a decrease in the number of head-on and angle crashes, but EB analysis shows an increase in all types of multiple-vehicle crashes.
3. Analysis of crash severity shows an increase in FI crashes and a decrease in PDO crashes.
4. The number of bike and pedestrian crashes has been shown to have increased.

Complete Streets Project Evaluation Summary

Study Site Information						
Road Name	From Road	To Road	Road Type	Jurisdiction	Before Period	After Period
Franklin Avenue	MRB	Cedar Ave.	Four Lane Undivided	Minneapolis, MN	1 Years	0.8 Years
AADT (veh/day)	Road Length (miles)	Speed Limit (mph)	Area Type	Improvement Type	Parking	
12,500	0.9	30	Urban	Lane Drop, Bike Lanes,	None	

Study Site Description, General Information, and Safety Issues

1. This study site is located in the City of Minneapolis; it is a minor arterial and previously had a four lane, undivided cross-section.
2. The property within the study site along Franklin Ave. is primarily commercial.
3. Sidewalks were present on both sides of the roadway prior to the re-construct.
4. There were no bicycle lanes prior to the re-construct.

Reconstruction Work

1. The roadway went through a lane reduction and now has two lanes, with a center turn lane at locations where turns onto intersecting streets can be made.
2. The original width of the roadway was maintained after the re-construct and sidewalks remained on both sides of the road.
3. Bicycle lanes were added to both sides of the road following the re-construct.