THE CITY OF Waterloo

TRANSPORTATION MASTER PLAN 2020 UPDATE

COMPENDIUM OF WORKING PAPERS

TRANSPORTATION MASTER PLAN UPDATE
LOOKING AHEAD

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COMPENDIUM OF WORKING PAPERS

This Compendium of Working Papers summarizes the policy and technical analysis carried out in completing the **City of Waterloo Transportation Master Plan (WTMP) Update**. The working papers detail the data collected, research conducted, analysis completed, and conclusions reached in preparing the WTMP document.

The reader should note the material contained in the WTMP may have evolved from the information presented in the working papers in response to comments received from stakeholders and reviewers on these foundational documents. Please refer to the WTMP for final guidance and recommendations.

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1 PLANNING CONTEXT

Technical Memorandum

Date: November 15, 2019

To: Christopher Hodgson, City of Waterloo

From: Gene Chartier, Paradigm Transportation Solutions Limited

c.c.: Kate Whitfield, Alta Planning + Design
Susan Hall, Lura Consulting

Re: **Planning Context**

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1 Introduction

This memorandum summarizes the transportation planning context for the **City of Waterloo Transportation Master Plan (TMP) Update**. The report is organized as follows:

- Chapter 2 summarizes applicable Province of Ontario plans, policies and regulations;
- Chapter 3 outlines relevant Region of Waterloo plans and policies; and
- Chapter 4 details other City of Waterloo plans and policies.

2 Province of Ontario

2.1 Provincial Policy Statement (2014)

Ontario's Provincial Policy Statement (PPS) provides policy direction matters of provincial interest related to land use planning and development, including transportation facilities. The *Planning Act* requires that all planning decisions "shall be consistent with" the PPS. With respect to Infrastructure and Public Service Facilities, the PPS policies indicates municipalities should:

- Provide infrastructure and public service facilities in a coordinated, efficient and cost-effective manner, considering climate change impacts while accommodating projected growth;
- Coordinate and integrate with land use planning to ensure financial viability and ability to meet current and projected needs;
- Promote green infrastructure in complement with infrastructure;
- Consider optimization and adaptive re-use of current infrastructure and public service facilities before developing new;
- Strategically locate to support effective and efficient delivery of emergency management systems; and

- Co-locate public service facilities in community hubs to promote cost-effectiveness, facility service integration and access to transit and active transportation.

Furthermore, the PPS sets out Transportation Systems policies which focus on the movement of people and goods through a safe and energy efficient transportation system, and promotes a multimodal transportation system, which includes transit and active transportation. This direction is supported through compact, mixed land uses and transportation demand management initiatives that minimize the length and amount of required motor vehicle trips.

Finally, with respect to transportation and infrastructure corridors, the PPS directs municipalities to:

- Plan and protect corridors and rights-of-way for transportation, transit and infrastructure facilities to meet current and projected needs;
- Restrict development in planned corridors that could preclude or negatively affect the use of the corridor for the purpose(s) for which it was identified;
- Encourage preservation and reuse of abandoned corridors for purposes that maintain the corridor's integrity and continuous linear characteristics; and
- Consider the environmental impacts when planning for corridors and rights-of-way for significant transportation infrastructure facilities.

2.2 Places to Grow Act and Growth Plan for the Greater Golden Horseshoe (Growth Plan, 2017)

The Growth Plan is a Provincial growth management plan that articulates a long-term strategic vision and tools for how the Greater Golden Horseshoe and surrounding areas should grow over the next 20 years. The Plan was developed to guide planning decisions in a way that will promote economic development and strong communities. The Plan directs municipalities to optimize the use of existing and new infrastructure to support growth, as well as coordinate infrastructure planning, land use planning and infrastructure investment in order to implement the Growth Plan.

Many policies in the Growth Plan deal with planning for transportation infrastructure, with emphasis on encouraging municipalities to plan for transportation systems that are adequate for the level of anticipated growth, offer multi-modal access to destinations, provide safety for users, and are interconnected and planned for in a coordinated manner. The Growth Plan also mirrors policies found in the PPS with respect to transportation corridors.

The Growth Plan also focuses heavily on planning for transit service levels that support higher density areas (such as the Uptown Waterloo Urban Growth Centre, *Major Transit Station Area*s), and increasing the modal share of transit. Further, municipalities are directed to integrate pedestrian and bicycle networks into transportation planning for both existing and new communities.

The Growth Plan contains a series of policies regarding community infrastructure. These policies provide direction for community infrastructure planning, land use planning and community infrastructure investment to be coordinated, to use such community infrastructure efficiently, and to plan for an appropriate range of community infrastructure to accommodate population changes.

2.3 Accessibility for Ontarians with Disabilities Act (2005)

The *Accessibility for Ontarians with Disabilities Act, 2005* (AODA) was enacted for the purpose of improving accessibility standards for Ontarians by 2025. The AODA outlines mandatory standards for private, public and non-profit sectors to remove barriers and ensure equitable access for all individuals with disabilities. Ontario Regulation 191/11 under the AODA establishes accessibility standards to apply when planning, designing and building transportation facilities, which will be referenced as part of the City of Waterloo TMP.

2.5 2041 Regional Transportation Plan for the Greater Toronto and Hamilton Area (2017)

The 2041 Regional Transportation Plan – the 2041 RTP - is about providing even more people with access to fast, frequent and reliable transit, and making it easier for travellers to use transit, or travel by bike or on foot. The 2041 RTP guides the continuing transformation of the transportation system in the Greater Toronto and Hamilton Area (GTHA). It is the blueprint for an integrated multimodal regional transportation system that puts the traveller's needs first.

Developed in partnership with municipal partners and many others, the 2041 RTP builds on the successes of The Big Move (2008), the first regional transportation plan for the GTHA. It presents a vision for the future, and sets out creating strong connections, complete travel experiences, and sustainable and healthy communities as the 2041 RTP's three goals. To achieve this vision and these three goals, the 2041 RTP outlines five strategies:

- Complete the delivery of current regional transit projects;
- Connect more of the region with frequent rapid transit;
- Optimize the transportation system;
- Integrate transportation and land use; and
- Prepare for an uncertain future.

With a view to reducing traffic congestion, improving air quality and supporting economic viability, the 2041 RTP provides a framework for the development of the TMP that considers all modes of transportation, promotes integration of local and regional public transit, and promotes transit-oriented development. The 2041 RTP includes improvements that will benefit mobility in Waterloo, specifically the action to strengthen connections between the GTHA and the Region of Waterloo, to support the economic prosperity of the GGH and the growth of one of North America's largest technology clusters.

2.6 Ministry of Transportation Transit Supportive Guidelines (2012)

The Province's Transit Supportive Guidelines promote transit-oriented planning and design throughout the province based on transit-friendly land use planning, urban design and operational best practices. The aim is to assist practitioners in creating environments that are supportive of transit and develop services and programs to increase transit ridership in communities over time. The document is structured into four key chapters with strategies applicable to all community scales including:

- Community-Wide Guidelines to create transit-supportive communities through a range of higher-level planning strategies.

- District-Level and Site-Specific Guidelines detailing design guidelines relating to streets, buildings infrastructure, and unique uses.
- Transit Improvement Guidelines noting transit improvement programs, innovations and services that can help to increase transit ridership.
- Implementation tools that can be used to achieve the principles and guidelines within the document.

2.5 #CycleON Ontario's Cycling Strategy (2013)

#CycleON: Ontario's Cycling Strategy is the province's 20-year plan designed to encourage the growth of cycling and improve the safety of people who cycle across the province. The Strategy's Vision is to have cycling in Ontario recognized, respected and valued as a core mode of transportation that provides individuals and communities with health, economic, environmental, social and other benefits by 2033. Achieving the Strategy's Vision requires a commitment from all partners for integrated action to:

- Design healthy, active and prosperous communities;
- Improve cycling infrastructure;
- Make highways and streets safer;
- Promote cycling awareness and behavioural shifts; and
- Increase cycling tourism in Ontario.

2.6 Ontario Trails Strategy

The Ontario Trails Strategy is a long-term plan that establishes strategic directions for planning, managing, promoting and using trails in Ontario. The Strategy recognizes trails as key economic and tourism assets for Ontario communities that, in addition to their economic benefits, bring important health benefits and contribute to a high quality of life. With a Vision to develop a world-class system of diversified trails, planned and used in an environmentally responsible manner, that enhances the health and prosperity of all Ontarians, the Strategy focuses on:

- Improving collaboration among stakeholders;
- Enhancing the sustainability of Ontario's trails;
- Enhancing the trail experience;
- Educating Ontarians about trails; and
- Fostering better health and a strong economy through trails.

3 Region of Waterloo

3.1 Region of Waterloo Official Plan

The Regional Official Plan (Plan) is the Regional Municipality of Waterloo's guiding document for directing growth and change for the next 20 years. The Plan represents a fundamental shift in shaping Waterloo Region towards a more balanced community structure, building from a strong, long standing planning policy framework that has supported substantial historical growth and change. The Plan lays

out the Region's policies for achieving key physical, transportation, environmental, social and economic objectives.

The vision of the Plan is that "*Waterloo Region will be an inclusive, thriving, and sustainable community committed to maintaining harmony between rural and urban areas and fostering opportunities for current and future generations".* With respect to infrastructure the Region's overall goal is to undertake infrastructure planning, development and asset management which optimizes the use of existing infrastructure, accommodates forecast growth, and promotes sustainability and a healthy population.

The transportation system policies seek to improve connectivity among transportation modes for the efficient movement of people and goods. The Region's transit system is a specific focus because of the strong link between land use and transportation planning, and the fact that the Region is the municipal transit authority. The transportation policies emphasize the need for collaboration between the Region and Area Municipalities when planning the transportation system.

3.2 Region of Waterloo Transportation Master Plan (2018)

Moving Forward is the 2018 Transportation Master Plan Update (TMP) for the Region of Waterloo. It is a strategic document that outlines the needs for active transportation (cycling and walking), public transit, and Regional roads to the year 2041. The TMP includes a series of Regional policies to encourage and shape sustainable travel and economic growth, to support land-use planning, and to support the Region as "a community where people matter and ideas grow."

Four overall goals for the plan were carried forward from the 2010 TMP, being:

- Promote Travel Choice
- Foster a Strong Economy
- Support Sustainable Development
- Optimize the Transportation System

Five broad strategies were developed to achieve the TMP's goals, each serving as an "umbrella" policy under which various actions should be undertaken:

- Build a Transportation Network that Supports all Modes of Travel
- Promote a Healthy Community
- Develop a Frequent Transit Network
- Enhance Inter-Regional Connections
- Position the Network for New Mobility

The TMP is an important foundational document for the City's Transportation Master Plan update. The plan provides importance background information and forms a basis for elements of the policy direction, network plans and infrastructure improvements to be captured in the City's updated transportation plan.

3.3 Walk Cycle Waterloo Region (2014)

Walk Cycle Waterloo Region is the Region of Waterloo's plan for making it easier to walk and cycle in the community. By promoting and integrating active forms of transportation, Walk Cycle Waterloo Region will help to achieve the Region's "Vision for a Sustainable and Liveable Waterloo Region" articulated in the Regional Official Plan.

Walk Cycle Waterloo Region looks at the people who live, work, study and play in the Region and considers where there is the potential for them to choose walking and cycling for short trips. The walking and cycling networks and supportive policies developed in the plan are designed to encourage cycling and walking. It consists of five Action Plans, plus new policy directions and a design guide intended to help the Region of Waterloo achieve the vision and goal of increasing the PM peak hour mode share for walking and cycling trips to 12% by 2031. The recommendations include a:

- Network Action Plan;
- Strategic Signage Action Plan;
- Winter Network Action Plan;
- Behavioural Shift Action Plan; and
- Performance Monitoring Action Plan.

4 City of Waterloo

4.1 City of Waterloo Strategic Plan

The City of Waterloo Strategic Plan serves as a community strategic plan that reflects the goals and priorities of the community, as well as a corporate strategy that serves to guide the municipality in how the city operates and delivers its services. The Strategic Plan outlines the framework and the steps that will be undertaken over the next four years to put the conditions in place to realize the City's vision: *"Waterloo is an equitable community that leads the world in learning, discovery and caring."*

The Strategic Plan outlines six strategic pillars or areas of focus that comprise the plan, guided by the principles of equity and inclusion, sustainability, fiscal responsibility, healthy and safe workplace, effective engagement, personal leadership and service excellence:

- Equity, inclusion, and a sense of belonging;
- Sustainability and the environment;
- Safe, sustainable transportation;
- Healthy community and resilient neighbourhoods;
- Infrastructure renewal; and
- Economic growth and development.

4.2 City of Waterloo Official Plan

The Official Plan is the primary long-range, comprehensive municipal planning document that outlines a framework for land use decision-making for the City of Waterloo. The Plan sets a broad, coordinated vision for all lands within the City, and supports the overall goal of achieving a healthy community built on the principles of diversity and adaptability, accessibility and equity, connectivity, health and vitality. Section 2.3 of the Plan outlines the following networks and transportation trends and factors that are considered to have a significant influence on the land use policies and designations of the Plan:

- Encourage active transportation as an alternative to the automobile;

- Plan for and support a shift in focus from providing roads to move cars, to providing streets where people can interact and travel on, whether by foot, bicycle, transit or other motorized vehicle;
- Support and contribute to the success of the public transit system;
- Continue to provide bicycle and vehicular parking that meets community needs while balancing needs of motorists and active transportation users; and
- Plan for trails and open space networks and supporting facilities that are interconnected and service transportation functions.

Achieving a healthy and livable City and a transportation system that is sustainable into the future will require placing increased emphasis on moving people –managing travel in order to reduce reliance on the automobile in favour of transit and more active forms of movement such as walking and cycling. Chapter 6 of the Plan outlines the following key areas of focus when planning for the most efficient use of new and existing networks that support the transportation system:

- Ensuring compact, mixed-use land use patterns, providing people with the opportunity to live close to where they are working, learning, shopping and playing;
- Planning for a comprehensive, multi-modal, well-connected transportation system that offers safe and convenient alternatives to automobile travel;
- Planning for safe and convenient pedestrian and cyclist movement, giving priority to these travel modes in the planning, design and operation of the City's networks (road and trails/open space) as well as in the design of sites and buildings;
- Increasing the proportion of trips made by transit travel by planning for a more compact, mixed-use City form that supports a comprehensive and efficient transit system, including rapid transit;
- Planning for the provision of appropriate bicycle and vehicular parking, balancing the desire for convenience with the desire to reduce automobile reliance.

4.3 Northdale Land Use and Community Improvement Plan Study – Urban Design and Built Form Guidelines

The City's Official Plan provides special design policies for several land use designations and the general urban design policy section. The Northdale Land Use and Community Improvement Plan (CIP) Study Official Plan Amendment provides supplemental design guidelines for the Northdale neighbourhood. The Official Plan provides policies that support a high standard of urban design for both public and private projects that contribute to an attractive and liveable City. The policies are further augmented with the City's Urban Design Manual, that provide more detailed guidelines for urban design, built form and landscaping.

The Northdale neighbourhood will develop incrementally, over time with a more consistent built form and streetscape pattern. The Guidelines provide guidance to facilitate intensification in the Northdale neighbourhood with emphasis on a compact, sustainable, mixed use neighbourhood that promotes active transportation, transit-oriented development, vital main streets and social neighbourhoods.

The purpose of the Northdale Urban Design Guidelines is to:

- Foster design excellence in the Northdale neighbourhood;

- Implement the Northdale Land Use and Community Improvement Plan Study Official Plan Amendment recommendations;
- Implement the City's Urban Design policies established in the Official Plan;
- Incrementally implement the vision for the Northdale neighbourhood;
- Provide specific built form, landscape and sustainable site and building design guidelines to assist Council in achieving the vision and principles established for Northdale;
- Provide eligibility criteria for the CIP's Financial Incentive Programs, with respect to design and sustainable development;
- Provide the City with a tool for the review and evaluation of development applications and financial incentive programs and supporting materials; and
- Provide supporting strategies for development implementation.

4.4 Uptown Public Realm Strategy

The City of Waterloo's Uptown Public Realm Strategy (UPRS) documents the study, engagement, visioning, and strategizing for the public realm of the civic, commercial and cultural heart of Waterloo. The vision for Waterloo's Uptown is to create a truly accessible, walkable, bikeable and transit supportive community with a high-quality public realm. The UPRS strives to seamlessly integrate a network of public and private parks and spaces to serve as nodes of dynamic public life.

The UPRS organizes the proposed improvements to Uptown into goals and actions based on five public realm systems: Parks and Open space, Connectivity; Urban Form, Heritage and Public Art and Culture. Furthermore, the public consultation process found reoccurring patterns, ideas and desire lines, which led to the development of three Priority Initiatives:

- **Laurel Greenway**, to transform the Laurel Trail into a linear park, characterized by open space, dense trees, attractive landscape, the Laurel Creek, and the multi-use Laurel Trail. With the new ION LRT station at it's centre and the established Waterloo Park to the West, the greenway creates a connected linear park and a swath of greenspace through the middle of Uptown.
- **Civic Common**, formed by Brewmeister's Green and Heritage Green marking the location of the original town square, and a new public space enhancing the Regional Waterworks site. The wider Civic District contains City and Region administrative buildings. These elements create a district of civic importance and symbol of civic pride. Improved streetscapes connect the spaces and tie the district to Allen Street LRT station which acts as the entrance to the Civic District.
- **Willis Way**, an active and attractive commercial street in Uptown. This street provides an east west connection in the middle of Uptown connecting to Barrel Warehouse Park to the west, Waterloo Cenotaph Park to the east, with the Public Square and the Public Square LRT Station in the middle.

These initiatives — the Laurel Greenway, the Civic Common, and Willis Way — will have maximum impact on the overall quality of Uptown's public realm and unite various goals across the five systems.

4.5 Rapid Transit Station Area Plans

The introduction of LRT through the heart of the City of Waterloo will connect significant employment lands, two major universities, Conestoga Mall, Waterloo Park, and residential neighbourhoods.

Introduction of the ION stations presents a tremendous opportunity to improve mobility, support placemaking, and create a series of vibrant, mixed-use communities along the corridor.

Eight of the Region's new LRT stops will fall within the City of Waterloo. The City has identified five for the development of more detailed "Station Area Plans". These areas generally include the lands within reasonable walking distance of the following stations: Laurier-Waterloo Park, University of Waterloo, Research and Technology, Northfield, and Conestoga.

The Station Area Plans will help guide change to capitalize on the opportunity of the LRT investment. The plans define a vision for the areas around the LRT stations and provide policy and design direction to guide development and public realm improvements to create a series of vibrant, attractive places to live, work, play and study.

The five Station Area Plans aim to:

- Encourage intensification around the future ION stations to increase transit ridership, encourage walking and cycling, and make more efficient use of the City's infrastructure and services;
- Promote community-building to support the unique character of each of the station areas and create attractive places for working, living, learning and recreation;
- Stimulate new investment and promote economic development by encouraging job growth and commercial vitality;
- Support placemaking through public realm improvements, public art, new open spaces and enhanced amenity; and
- Create the basis for regulatory amendments, including updates to the Official Plan, Zoning By-law, and urban design guidelines.

2 REGION OF WATERLOO TRANSPORTATION MASTER PLAN SUMMARY

Technical Memorandum

Date: November 15, 2019

To: Christopher Hodgson, City of Waterloo

From: Gene Chartier, Paradigm Transportation Solutions Limited

c.c.: Kate Whitfield, Alta Planning + Design
Susan Hall, Lura Consulting

Re: **Region of Waterloo Transportation Master Plan Summary**

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1 Introduction

This memorandum provides a summary of the Region of Waterloo 2018 Transportation Master Plan (2018 RTMP)[1] and its implications for the **City of Waterloo Transportation Master Plan (TMP) Update**. The report is organized as follows:

- Chapter 2 provides an overview of the 2018 RTMP;
- Chapter 3 outlines the 2018 RTMP vision and goals;
- Chapter 4 details strategies and key directions of the 2018 RTMP; and
- Chapter 5 summarizes the key considerations pertaining to the City of Waterloo to incorporate in the TMP Update.

2 Regional Transportation Master Plan Overview

The 2018 Regional Transportation Master Plan Update is the third version of the Region of Waterloo's long-term transportation strategy and supersedes the previous plan approved by Regional Council in 2010. The 2010 RTMP was a transit-oriented plan with a strong focus on more sustainable modes of travel, such as walking, cycling, and public transit. Since adoption, the Region kept pace with the infrastructure and transit service improvements identified in the 2010 RTMP and has completed or is in the process of completing the action items stated in the plan. Over this period the Region has also experienced rapid growth, the completion of several major infrastructure improvements and transformational changes in travel behaviour due to technology.

Considering these factors, the Region initiated an update to its Transportation Master Plan in 2016, which culminated in the approval of *Moving Forward: 2018 Transportation Master Plan Update* (2018

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[1] IBI Group. *Region of Waterloo Moving Forward: 2018 Transportation Master Plan.* June 2019.

RTMP) by Regional Council in June 2018. Like previous versions, the 2018 RTMP is a strategic document that outlines the needs for active transportation (cycling and walking), public transit, and Regional roads to the year 2041. The plan includes a series of Regional policies to encourage and shape sustainable travel and economic growth, support land-use planning, and aid the Region in becoming "a community where people matter and ideas grow."

3 Vision and Goals

Through the consultation process, the following vision statement was developed for the 2018 RTMP:

Waterloo Region will be a prosperous, sustainable, and healthy community, with viable transportation choices for people of all ages and abilities, and for the goods supporting our economy.

To aid in realizing this vision, the following four goals developed for the 2010 RTMP were carried forward:

- **Promote Travel Choice** – Promoting travel choice focuses on transportation equity, ensuring that everyone within the Region can make trips in an integrated and seamless manner without having to drive (or own) a car. This goal also considers whether different ways of making trips, such as walking, cycling, and public transit, are competitive in terms of travel time, cost, and accessibility.
- **Foster a Strong Economy** – The Region's transportation system plays a major role in supporting the regional economy. It is important to propose changes to the transportation system that will make the economy more resilient and promote a healthy workforce. These changes may include improving the quality of active transportation (walking and cycling) options in the Region, finding ways to manage congestion, or improving travel times along major goods movement corridors.
- **Support Sustainable Development** – Supporting sustainable development is both an economic and environmental goal as it relates to transportation. Specifically, the plan will support sustainable growth in both urban and rural areas while reducing transportation contributions to climate change.
- **Optimize the Transportation System** – The final goal is to optimize the transportation system by making the most of infrastructure and services that already exist. Managing transportation supply and demand will help to maximize the use of existing facilities and defer the need for new infrastructure that does not support the other goals.

4 Strategies and Action Items

The following five broad strategies were developed to support and advance the 2018 RTMP transportation vision and goals. The strategies serve as "umbrella" policies under which specific actions or projects pertaining to active transportation, transportation demand management, Grand River Transit, roads and transportation system management, new mobility, and goods movement should be undertaken. The strategic directions in **bold** are specific actions the City should consider in its TMP Update, as further discussed in **Chapter 5.**

4.1 Strategy 1 – Build a Transportation Network that Supports all Modes of Travel

Strategy 1 defines the transportation network developed through the scenario evaluation needed to meet future needs to the year 2041 (and beyond). This network explicitly supports travel by different modes (walking, cycling, transit and traffic) and goods movement.

The road network defined for Strategy 1 was developed by carrying forward the best road, transit, and active transportation projects from the 2010 RTMP, deferring some lower-performing road projects, and adding the best-performing transit and active transportation infrastructure works from the preferred scenario. Road system management and goods movement are also included in this strategy.

Building on the road projects, road system management and safety considerations, and goods movement strategies identified under this strategy, the Region adopted the following six policy directions to build a transportation network that supports all modes of travel:

- Complete projects in progress to provide a foundation for a multi-modal focus moving forward;
- **Slowly implement future road widening to match growth and development;**
- Review Regional Corridor Design Guidelines to ensure they support urban intensification, enhance comfort and convenience for all users, encourage reduced traffic speeds, and accommodate all modes of transportation;
- **Support reduced or eliminated parking rate minimums in area municipal zoning bylaws for new developments;**
- Undertake a goods movement study to identify how the Region could manage the transportation system differently to respond to local needs or changes in society and technology; and
- **Proactively manage demand by funding transportation demand management initiatives aimed at reducing the need for travel or the shifting of trips to different times, routes, or modes.**

4.2 Strategy 2 – Promote a Healthy Community

A key message heard from the public through the consultation process for the 2018 RTMP was the need to support healthy lifestyles and a healthy community. The plan makes promoting a healthy community one of its feature strategies by encouraging sustainable transportation choices, which have positive impacts on public health, safety, and the environment. This also helps to foster the connection between active transportation, transit and health.

Strategy 2 identifies two specific topics relating directly to public health:

- Continuing to support active transportation through recommended walking and cycling network and facility upgrades; and
- Continuing and expanding the transportation demand management program and delivery framework.

Based on the walking and cycling projects and transportation demand management strategies discussed under this strategy, the Region adopted the following policy directions to promote a healthy community:

- Update and Incorporate the Active Transportation Master Plan:
  - Identify opportunities to upgrade facilities to improve separation from traffic;
  - Identify opportunities for, and implement, crossings of major barriers;
  - Enhance network connections;
  - Enhance walk and bike access to transit; and
  - Integrate active transportation with municipal facilities and designations.
- **Emphasize safe, active travel for children travelling to/from school and other destinations;**
- **Continue to engage with other stakeholders to emphasize safety in design and monitoring**; and
- Define and measure the health benefits for people walking, cycling, and taking public transit in and around the Region**.**

4.3 Strategy 3 – Develop a Frequent Transit Network

The 2018 RTMP targets a 11.8% reduction in auto driver mode share over the life of the plan. The best (and only) way to meet this target is to develop a transit network that supports the travel needs of the broad public. This requires building on the existing transit network and services provided by Grand River Transit (GRT) and continuing an aggressive expansion in transit service to 2041.

Strategy 3 details the recommended 2041 transit network, new routes and services, transit infrastructure improvements, new transit service delivery models and transit needs beyond 2041. Based on the enhanced transit service and new transit infrastructure plan detailed in the strategy, the Region adopted the following six policy directions to develop a frequent transit network:

- Extend ION to Cambridge (ION Stage 2);
- Implement a frequent transit network that provides high quality 10-minute or better service all day by 2041;
- Identify additional corridors for future rapid transit;
- **Continue to encourage land use intensification along transit corridors;**
- Include transit priority measures in capital budgets to maintain or improve time-competitiveness with cars; and
- Investigate smaller scale, more flexible transit to provide service to underserved areas.

4.4 Strategy 4 – Enhance Inter-Regional Connections

The 2018 TMP identified growth in travel to and from key destinations external to the Region, including Guelph, Peel Region, Hamilton, Halton Region, and Toronto, as a concern requiring attention. Improved road and transit connections to the Greater Toronto Area, the rest of Ontario, and beyond are needed to support the Region's important position in the provincial economy and encourage growth locally.

Strategy 4 details the interregional transit links, road and highway connections and goods movement network required to facilitate longer-distance travel and encourage use of more sustainable modes where possible. The Region adopted the following three policy directions to enhance these critical inter-regional connections:

- Support and promote enhanced connections, such as GO Regional Express Rail, High Speed Rail and GO Bus, with the Greater Toronto and Hamilton Area and with other destinations such as Guelph, London, Brantford, and the Region of Waterloo International Airport.
- Work with the Ministry of Transportation and support managed lanes on Provincial Highways, such as dedicated high-occupancy vehicle lanes, high-occupancy toll lanes, or truck lanes.
- **Support goods movement with a balanced plan that maintains service levels, accessibility, and safety, and accommodates all modes in Regional corridors.**

4.5 Strategy 5 – Position the Region for New Mobility

Although early, it will be important for the Region to support the technology sector while maximizing the benefits of new mobility and minimizing the potential negative consequences.

Strategy 5 provides some early direction for Regional policy in this field of new mobility. The strategy explores a variety of new mobility technologies, including connected and autonomous vehicles, auxiliary taxis, and demand-responsive transit, and identifies ways in which these options can be part of an integrated and sustainable future transportation system in the Region of Waterloo.

Based on the new mobility services and technologies discussed under this strategy, and the potential transportation futures they offer, the Region adopted the following eight policy directions to position itself for new mobility:

- Integrate mobility services with public transit, such as through a shared payment platform that would enable users to buy mobility on a variety of different modes;
- Consider subsidized ride-hailing for areas of the Region with limited or no public transit;
- Consider rethinking how ride-hailing providers are regulated;
- Examine on-demand and dynamically routed public transit service that would enable transit services to modify existing routes based on demand;
- **Investigate road user charging and other policies, such as parking cost, to help manage demand, manage traffic congestion, and provide additional sources of revenue;**
- Plan for a driverless ride-hailing pilot program to learn how new technologies and delivery models for transportation can enhance mobility in the Region;
- **Develop a New Mobility Action Plan that includes specific objectives and actions to support the above initiatives**; and
- Update Regional Council annually on any developments in the technology and staff's progress on the New Mobility Action Plan.

5 Key Considerations for City of Waterloo Transportation Master Plan Update

The 2018 RTMP sets the framework for the transportation network in the Region of Waterloo to 2041. To achieve the vision set out in the plan, transportation goals and actions of the lower-tier municipalities must align. For this reason, the four goals of the 2018 RTMP should be reflected in the TMP Update (as they apply).

The TMP Update should also consider inclusion of the specific actions highlighted in the strategic directions outlined in **Chapter 4**, especially the actions where the City is identified to take the lead role. As the Region develops and implements the policies outlined in the 2018 RTMP, the City should support and work in conjunction with the Region to ensure the transportation goals are met.

In addition, the following road, active transportation and transit network plans should be referenced and incorporated (where appropriate) in the TMP Update. Where possible, connections should be provided between City and Region infrastructure to create a seamless transportation network consistent with the direction of the 2018 RTMP and the Update TMP:

- **Table 1** details the Regional Road projects to 2041 and beyond (2018 RTMP Exhibits 5.1 5.2 and 5.3);
- **Figure 1Error! Reference source not found.** displays the 2041 Regional active transportation network (2018 RTMP Exhibit 5.9);
- **Figure 2** shows the recommended 2041 transit network (2018 RTMP Exhibit 5.14); and
- **Figure 3** indicates transit corridors for protection beyond 2041 (2018 RTMP Exhibit 5.19).

From a technical perspective, the TMP Update should rely on travel demand forecasting models and other data developed in preparing the 2018 RTMP to ensure consistency in assumptions and analysis approach.

As noted in **Section 4.3**, a key policy direction of the RTMP is to increase the physical separation between motor vehicles and cyclists where possible. **Figure 1** reflects this direction, identifying several corridors to upgrade proposed bike lanes to separated (protected) facilities. Protected cycling facilities are desirable for several reasons, including:

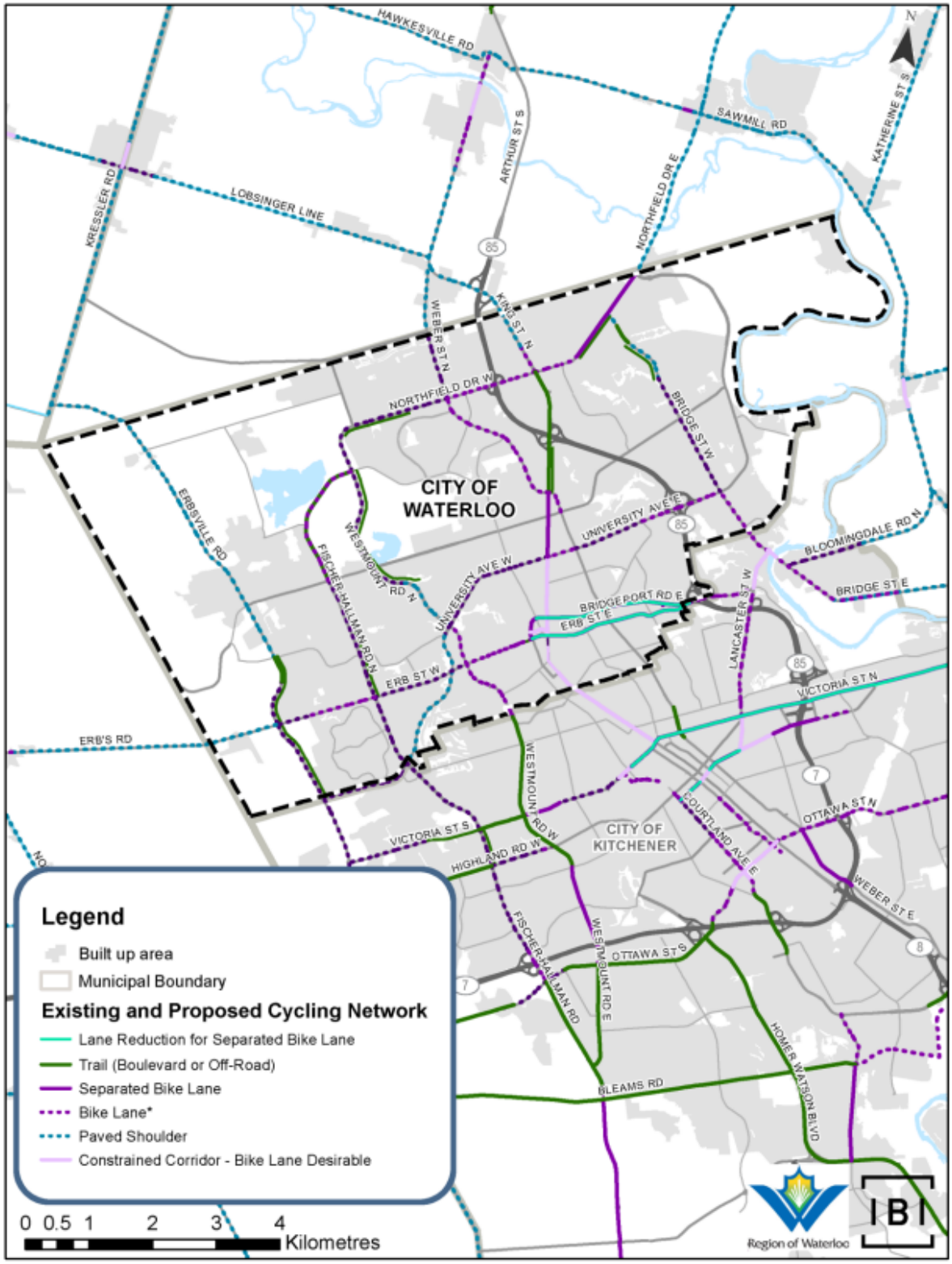
- Arterial roads typically serve more than 10,000 vehicles per day at speeds equal to or greater than 50 km/h. These types of roadways can make cycling intimidating or uncomfortable without separation;
- There is a desire to attract the “Interested but Concerned” user to cycling. Emerging best practice in the field of bicycle planning and design recognizes the importance of separated facilities in attracting new riders; and
- The thoughtful design of separated facilities at intersections provides more opportunities to implement bicycle priority measures, such as protected intersections and/or leading and protected cycling signal phases.

The TMP Update should consider protected cycling facilities along City roadways to align with the broader vision for the Region.

In anticipation of needs beyond the RTMP horizon year of 2041, the RTMP identifies several road and rail corridors for potential future transit service. **Figure 3** presents the corridors for protection in the City of Waterloo, which are subject to further review and refinement prior to implementation. Within the City, the Erb Street West – University Avenue West – King Street North (from Ira Needles Boulevard to Conestoga Mall) corridor should be protected for potential ION Stage 3 rapid transit. This initiative would build on the existing ION LRT (Stages 1 and 2) service to provide east-west connections in Waterloo. While potential future transit service on this corridor is beyond the horizon of the TMP Update, the City should continue to monitor the status of ION Stage 3.

Table 1: Recommended Waterloo Region Road Projects (City of Waterloo)

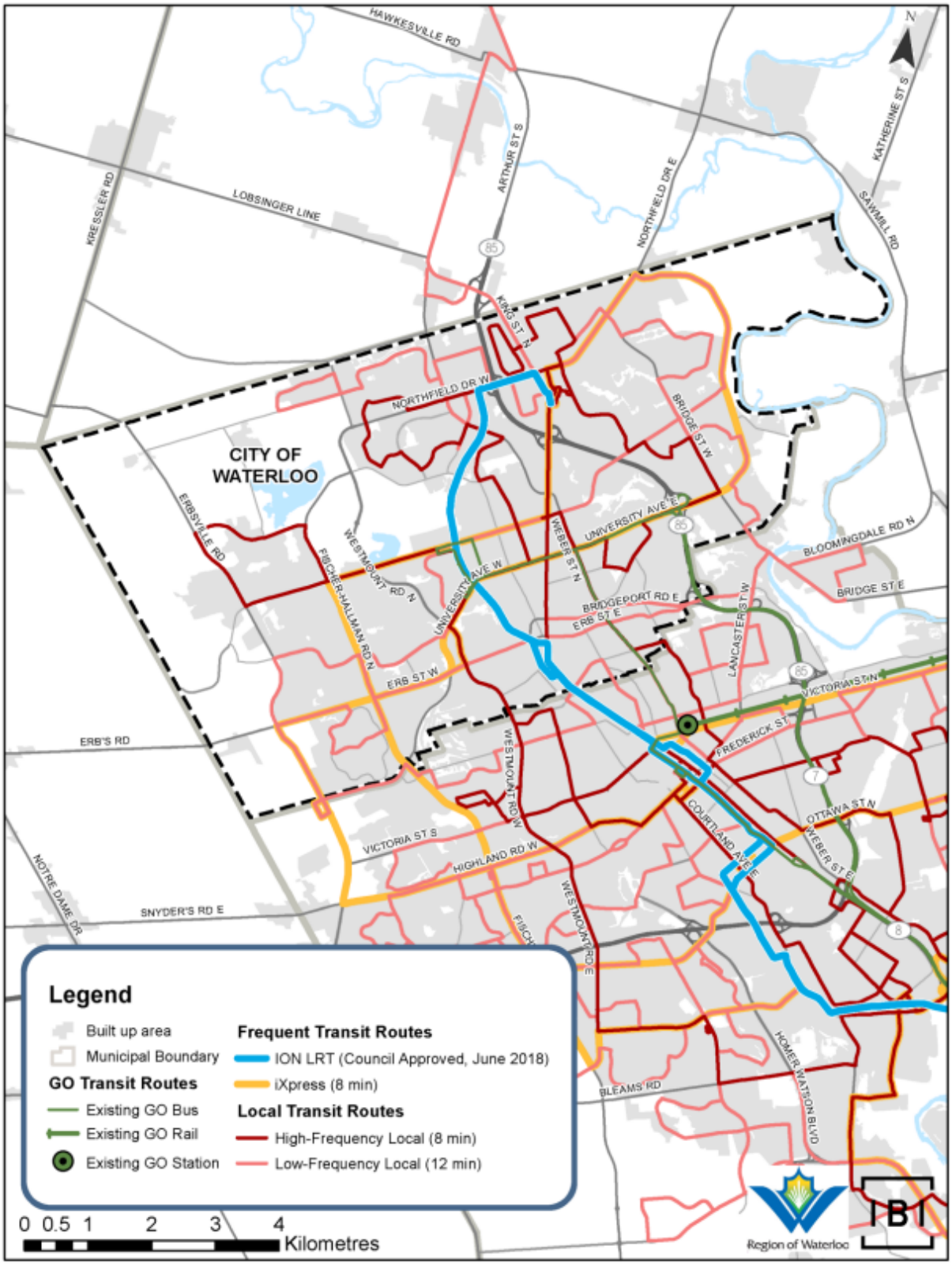
No.	Street	Type	Limits
2019 – 2031 Projects			
3	Northfield Drive East	Widening	Davenport Road to University Avenue
9	Fischer-Hallman Road /Bearinger Road	Extension	Columbia Street to Westmount Road
11	Erb Street West	Widening	Gateway Drive/Beechwood Drive to Wilmot Line
12	University Avenue West	Widening	Keats Way to Erb Street
14	University Avenue West	Widening	Ira Needles Boulevard to Fischer-Hallman Road South
16	Fischer-Hallman Road	Widening for Transit Lanes	Highway 7/8 to Columbia Street
A	Bridgeport Road/Caroline Street North	Road Diet	Highway 85 to Erb Street West
2031 – 2041 Projects			
10	Erbsville Road	Widening	Erb Street to Columbia Street
B	Erb Street West	Road Diet	Fischer-Hallman Road to Belmont Avenue West
Projects Beyond 2041			
73	King Street North	Widening	Northland Road to Bridge Street West
74	Erbsville Road	Widening	Columbia Street West to Wideman Road



* Opportunities to upgrade proposed bike lanes to protected cycling facilities

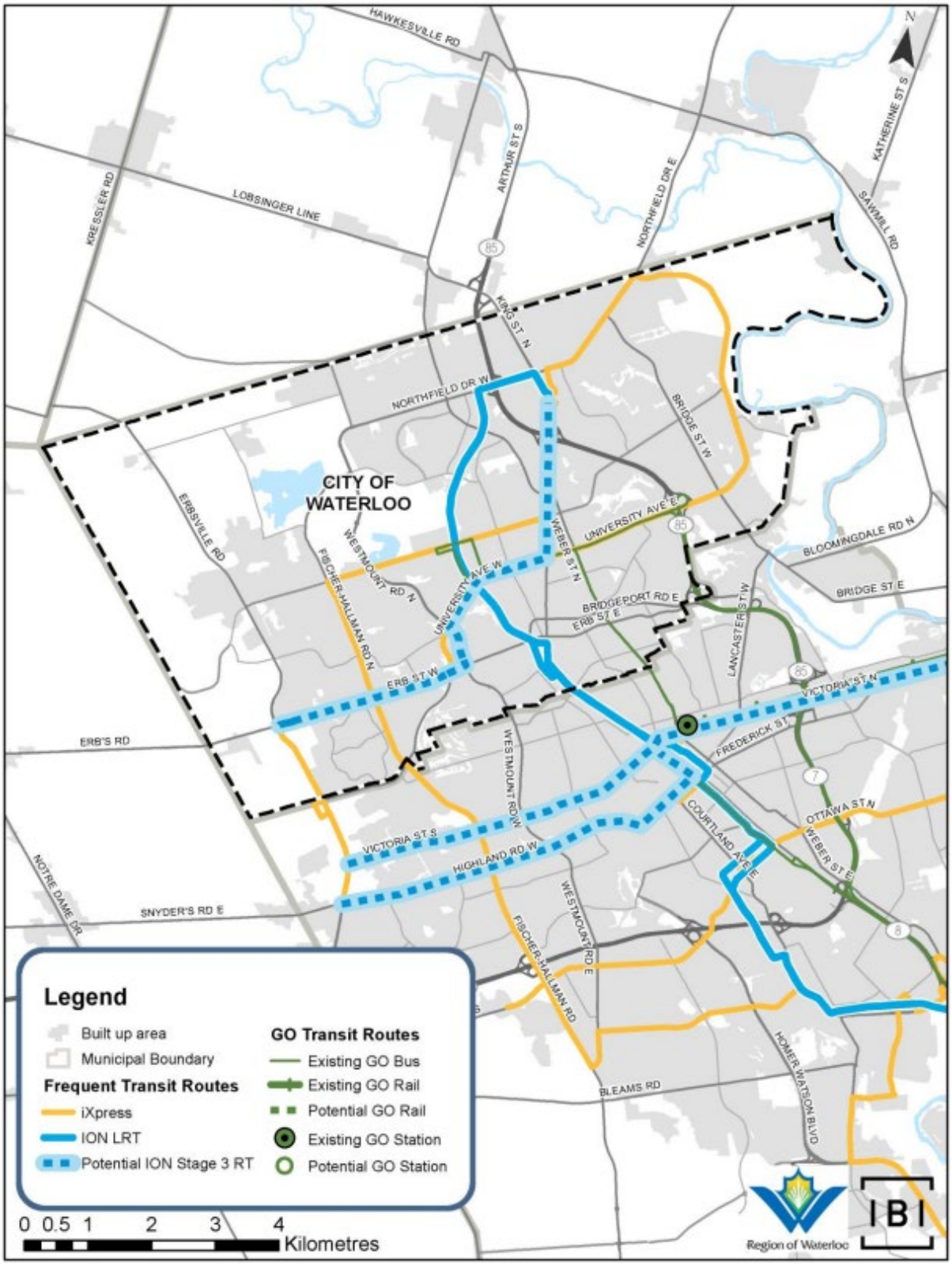
2041 WATERLOO REGION ACTIVE TRANSPORTATION NETWORK (WATERLOO)

Figure 1



RECOMMENDED 2041 WATERLOO REGION GRT AND ION NETWORK (WATERLOO)

Figure 2



WATERLOO REGION TRANSIT CORRIDORS FOR PROTECTION BEYOND 2041 (WATERLOO)

Figure 3

3 EXISTING TRAVEL TRENDS

Technical Memorandum

Date: November 28, 2019

To: Christopher Hodgson, City of Waterloo

From: Gene Chartier, Paradigm Transportation Solutions Limited

c.c.: Kate Whitfield, Alta Planning + Design
Susan Hall, Lura Consulting

Re: **Existing Travel Trends**

---

1 Introduction

This memorandum highlights changes in city-wide travel characteristics to be considered in the **City of Waterloo Transportation Master Plan (TMP) Update**, as revealed by data collected through the 2011 and 2016 Transportation Tomorrow Survey (TTS). The review analyzed the same travel characteristics reported in the *City of Waterloo Active Transportation Trends, 2006-2011 Technical Memorandum* to provide an indication of change over time0F[1].

It is important to recognize that the 2016 TTS data will only somewhat reflect the outcomes of policies, programs and infrastructure improvements recommended in the current Transportation Master Plan adopted by City Council in 2011. In most cases, changes in travel behaviour resulting from policy, regulatory and infrastructural transformation of this nature will only become evident after many years. Future iterations of the survey will provide a more fulsome retrospective of the impact of this plan's directions on how people travel in and around Waterloo.

The remainder of this report is organized as follows:

- Chapter 2 describes the changes in the TTS survey methodology for 2016;
- Chapter 3 presents the analysis of data from the 2016 TTS;
- Chapter 4 discusses changes in travel behaviour observed between 2011 and 2016, with a focus on the most significant shifts noted in active transportation use;
- Chapter 5 outlines the potential impacts of the new ION Light Rail Transit (LRT) service on travel patterns within the City of Waterloo; and
- Chapter 6 provides a short summary of the key trends and changes between 2011 and 2016.

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[1] IBI Group. *Technical Memorandum: City of Waterloo Active Transportation Trends, 2006-2011.* January 2015.

2 2016 Transportation Tomorrow Survey

2.1 Overview

The Transportation Tomorrow Survey (TTS) is a confidential and voluntary survey on how Ontarians in the Greater Golden Horseshoe (GGH) travel. The research helps local and regional governments, as well as the province and its agencies, make better informed transportation planning and investment decisions. The seventh in a series of surveys conducted every five years since 1986, the 2016 edition of the TTS was one of the largest and most comprehensive travel surveys ever completed in North America.1F[2]

The original concept for the 2016 TTS was to replicate the 2011 TTS using a telephone survey and directory sampling approach solely. However, the potential for sampling bias and data collection challenges, given the growth in cell phone use and decline in households with a landline, necessitated a revision in the survey methodology to address-based sampling and introduction of an online version. These changes enabled the 2016 TTS to connect with a more representative sample of households than the traditional landline telephone sampling and survey methods alone. Both online and telephone surveys were used concurrently throughout the survey period in fall of 2016.

This change in methodology is particularly relevant for the City of Waterloo given its large student population. The inability to complete surveys of a certain group of non-respondent populations, like university students who are more likely to have cell phones than landlines, introduces bias into the dataset. Students also tend to be under-represented because many live on campus and would not be included in a telephone directory sample. As such, the 2016 TTS approach is expected to provide more representative data sample for the City than previous editions of the survey.

The 2016 TTS did not provide data summaries at the electoral ward level for the City of Waterloo. To allow for comparisons on this geographical basis, data provided for the Traffic Analysis Zones (TAZs) within the City were aggregated to the ward level. In cases where the TAZ straddled a ward boundary, the data were disaggregated and assigned proportionally based on the relative area of the TAZ falling within each ward.

2.2 Survey Methodology Changes

For the 2016 TTS, changes were made to both the sample frame and data expansion process. As noted above, address-only and a small portion of phone-only samples were added to the conventional directory-listed phone with address samples to minimize coverage bias. In addition, an iterative proportional fitting method was used in data expansion to adjust the household weights using the control variables of dwelling type, household size, and householder age and gender. Due to these changes, caution should be exercised when making historical comparisons of survey results.

The data presented in this memo were extracted directly from the TTS database and not adjusted.

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[2] R.A. Malatest and Associates Ltd. *2016 Transportation Tomorrow Survey, Design and Conduct of the Survey.* May 2018.

3 2016 Travel Characteristics

3.1 Travel Behaviour

Table 1 and **Table 2** summarize the vehicle ownership and trip making characteristics, respectively, reported for the City of Waterloo in the 2016 TTS. Daily and morning peak period (06:00 to 08:59) travel trends are provided. The population and household values cited in **Table 1** were obtained from the 2016 Statistics Canada Census of Population.

The following observations were noted from the 2016 TTS data:

- Households in the City of Waterloo own an average of 1.58 vehicles;
- Residents in the City average 2.30 daily trips per person and about 6 daily trips per household. Approximately 20% of these trips are made during the three-hour morning peak period;
- Residents of Waterloo travel mostly to points within the City, with about 60% of morning peak period trips destined locally. The City of Kitchener is the next most common destination, with about 25% of morning peak period trips ending in the adjacent municipality;
- As **Figure 1** shows, approximately 40% of daily trips originating in the City are made for home-based discretionary purposes. Home-based work (29%), non home-based (18%) and home-based school (14%) are the next most common trip purposes. During the morning peak period, home-based work (49%) and home-based school (22%) trips are more prevalent than home-based discretionary (20%) and non home-based (10%); and
- As **Figure 2** illustrates, private auto driver (67%) and passenger (13%) are the most common travel modes for trips originating in the City, followed by walking (7%), public transit (7%) and cycling (3%). Travel by other modes such as school bus, taxi and rideshare comprise the remainder. Mode choice does not vary considerably for trips made during the morning peak period, with slight increases in walking (9%) and other mode (6%, mostly school bus) use noted.

Table 1: Population, Household and Vehicle Ownership Characteristics, 2016

Characteristic	Unit/Type	Value
Population	*From 2016 Census*	104,985
Households	*From 2016 Census*	40,380
Average Vehicle Ownership	Per Household	1.58

Source: 2016 Census of Population and 2016 Transportation Tomorrow Survey

Table 2: Trip Making Characteristics, 2016

Characteristic	Unit/Type	Daily (24 hours)	AM Peak Period (06:00 to 08:59)
Trips	Originating in Waterloo	276,100	51,030 (18% of daily)
	Made by Waterloo Residents	241,700	50,150 (21% of daily)
For Trips Made by Waterloo Residents:			
Trip Rate	Per Person	2.30	0.48
	Per Household	5.99	1.24
Trip Destination	Waterloo	185,600 (77%)	29,250 (58%)
	Kitchener	34,800 (14%)	12,530 (25%)
	Cambridge	4,500 (2%)	2,260 (5%)
	Townships	6,600 (3%)	2,200 (4%)
	Outside Waterloo Region	10,200 (4%)	3,910 (8%)
For Trips Originating in Waterloo:			
Trip Purpose	Home-Based Work	80,400 (29%)	25,050 (49%)
	Home-Based School	37,600 (14%)	11,010 (22%)
	Home-Based Discretionary	109,500 (40%)	10,070 (20%)
	Non Home-Based	48,600 (18%)	4,900 (10%)
Travel Mode	Walk	20,200 (7%)	4,800 (9%)
	Cycle	7,500 (3%)	1,660 (3%)
	Transit	18,100 (7%)	3,240 (6%)
	Auto Passenger	36,800 (13%)	5,040 (10%)
	Auto Driver	185,700 (67%)	33,330 (65%)
	Other	7,800 (3%)	2,960 (6%)

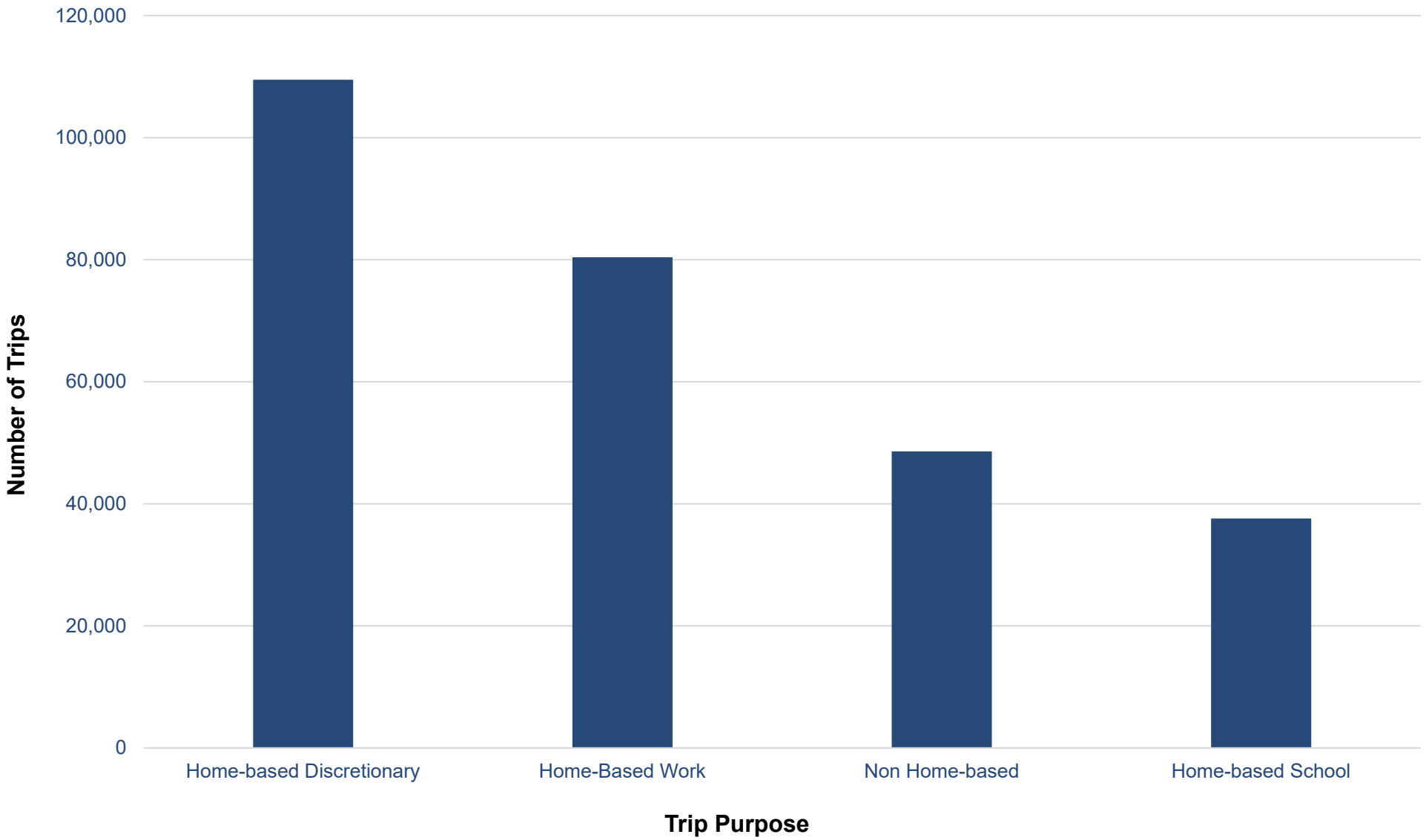
Source: 2016 Transportation Tomorrow Survey

3.2 Trips Within Walking and Cycling Distance

The length of trips originating in the City of Waterloo were examined to assess the potential for increased walking and cycling use. In most cases, trips less than 2 km can be made effectively by walking, while cycling is a viable travel mode for trips up to 8 km.

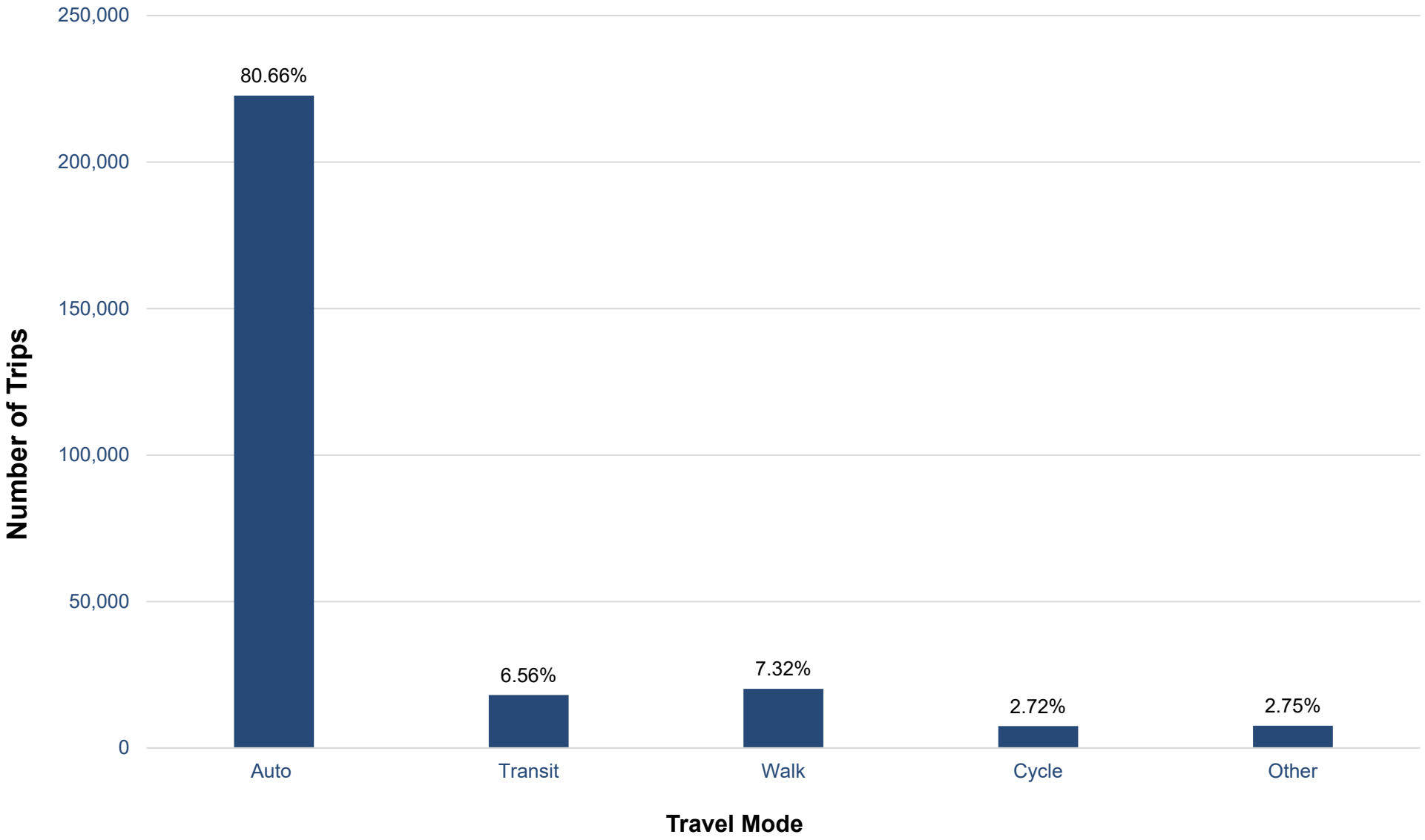
The following observations were noted from the 2016 TTS data:

- 90,700 (33%) daily trips originating in the City of Waterloo are less than or equal to 2 km based on Manhattan length, which is the distance between two points measured along axes at right angles. Of these trips, about 19,500 (21%) were made by walking and 4,200 (5%) were made by cycling; and
- 115,000 (42%) daily trips originating in the City were greater than 2 km but less than or equal to 8 km based on Manhattan length. Of these trips, only 600 (1%) were made by walking and 2,800 (2%) were made by cycling.



TRIPS BY TRIP PURPOSE, 2016

Figure 1



TRIP MODE SHARE, 2016

Figure 2

Table 3 summarizes the percentage of daily trips within cycling distance (i.e. less than or equal to 8 km in length) by ward. The walking and cycling mode shares for these trips are also noted.

Table 3: Active Transportation Proportion and Mode Shares for Trips 8 km or Less by Ward, 2016

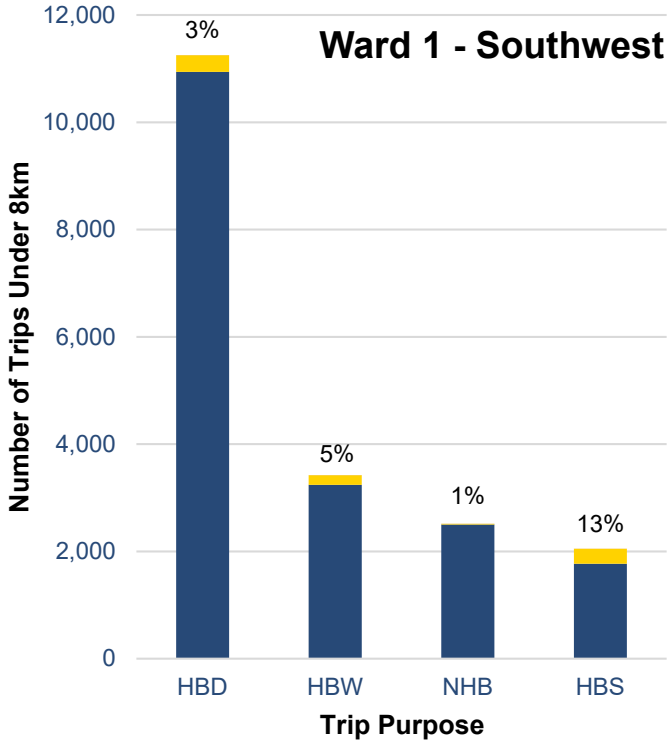
Ward	% of Daily Trips ≤ 8 km	% Walk for Trips ≤ 8 km	% Bike for Trips ≤ 8 km
Ward 1 – Southwest	79%	3%	1%
Ward 2 – Northwest	72%	11%	2%
Ward 3 – Lakeshore	71%	6%	2%
Ward 4 – Northeast	64%	5%	2%
Ward 5 – Southeast	78%	5%	3%
Ward 6 – Central-Columbia	77%	15%	5%
Ward 7 – Uptown	81%	14%	6%
City of Waterloo	**75%**	**10%**	**3%**

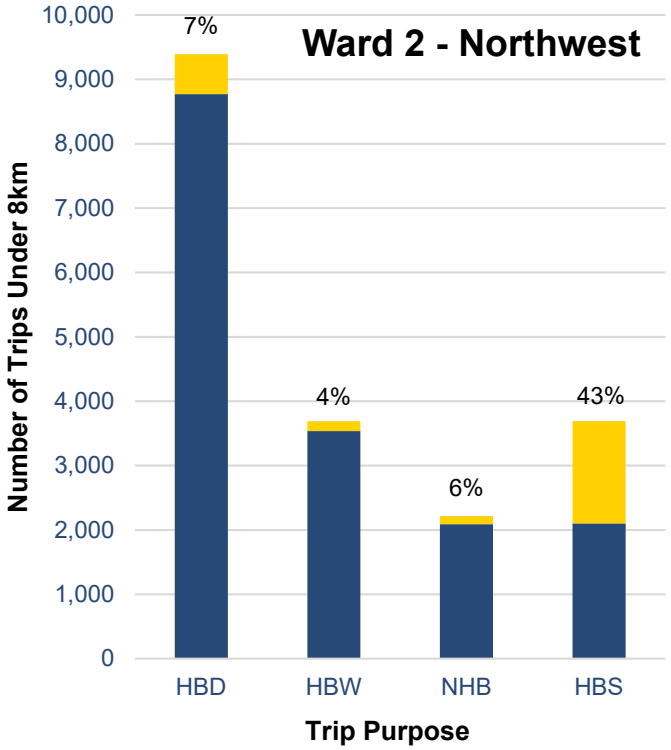
Source: 2016 Transportation Tomorrow Survey

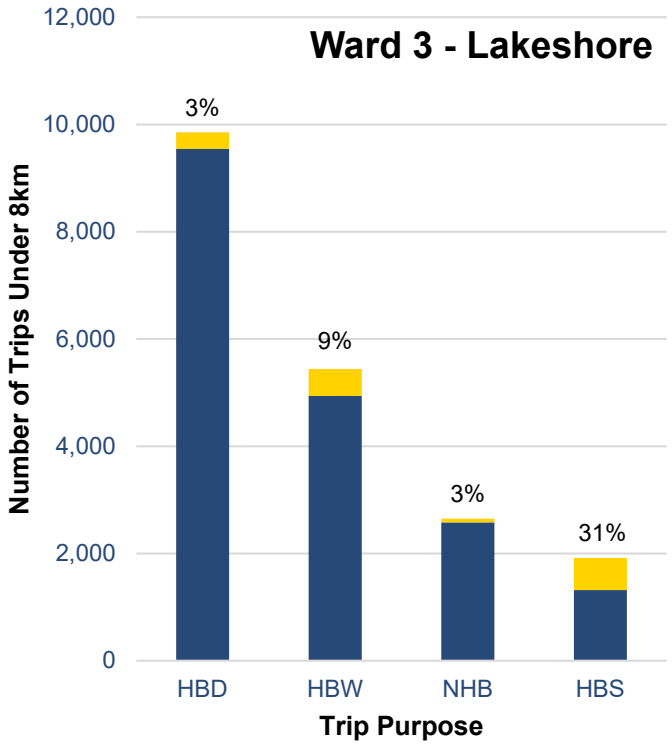
According to the 2016 TTS data, approximately 75% of all trips on a typical weekday in the City of Waterloo are within cycling distance, but only 13% are made using active modes. **Figure 3** shows the distribution of trips within cycling distance by trip purpose and mode for each ward.

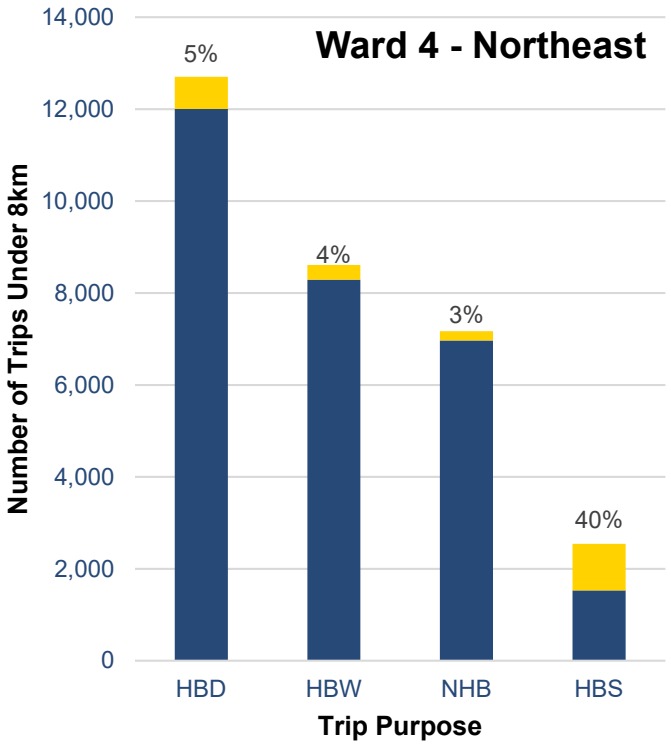
Other observations noted from the data include:

- In all wards, **home-based discretionary** is the most commonly cited purpose for trips 8 km or less, with 9,000 to 16,000 daily trips reported per ward in the City. However, outside of Ward 6 – Central-Columbia (12%) and Ward 7 – Uptown (12%), walking and cycling trips represent a relatively small share of this travel demand (7% or less);
- Many **home-based school trips** 8 km or less are made by walking or cycling, ranging from 13% to 57% by ward. The highest walking and cycling mode shares for these trips were reported in Ward 2 – Northwest (40%), Ward 4 – Northeast (40%), and Ward 7 – Uptown (57%);
- Ward 6 – Central-Columbia (20%) and Ward 7 – Uptown (28%) have the highest portions of **home-based work trips** 8 km or less made by walking and cycling. In the other five wards, the share of trips by active transportation modes varies between 4 and 9%; and
- A higher proportion of **non home-based** trips 8 km or less are made by walking and cycling in Ward 7 – Uptown (10%) and Ward 6 – Central-Columbia (11%). In the other five wards, less than 6% of these trips are made using active modes.



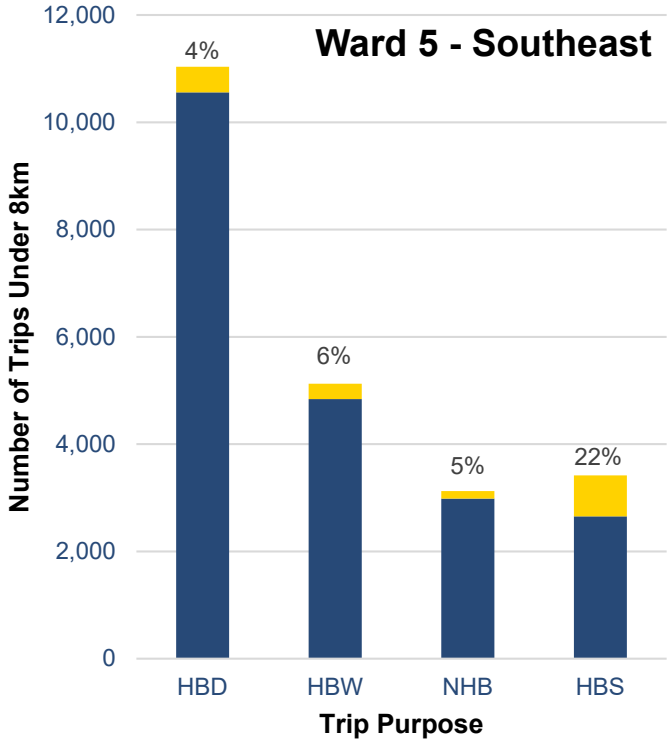


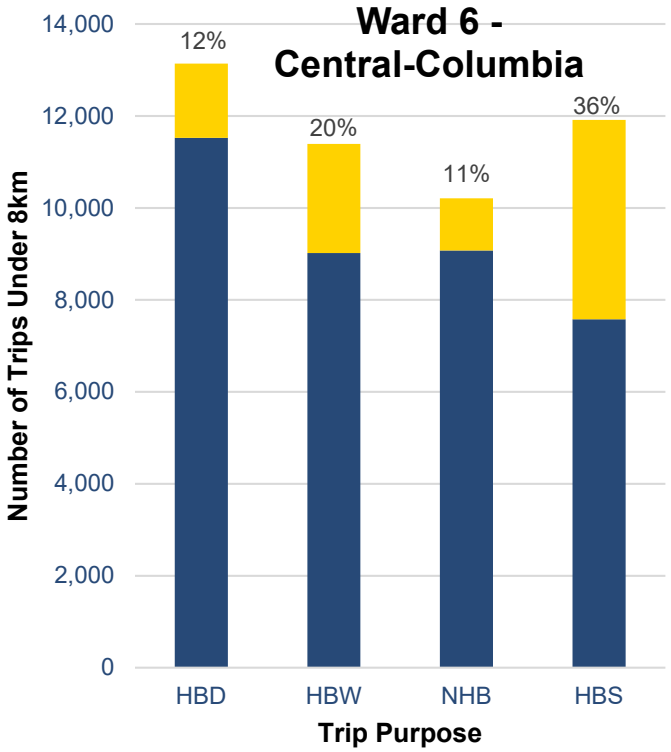


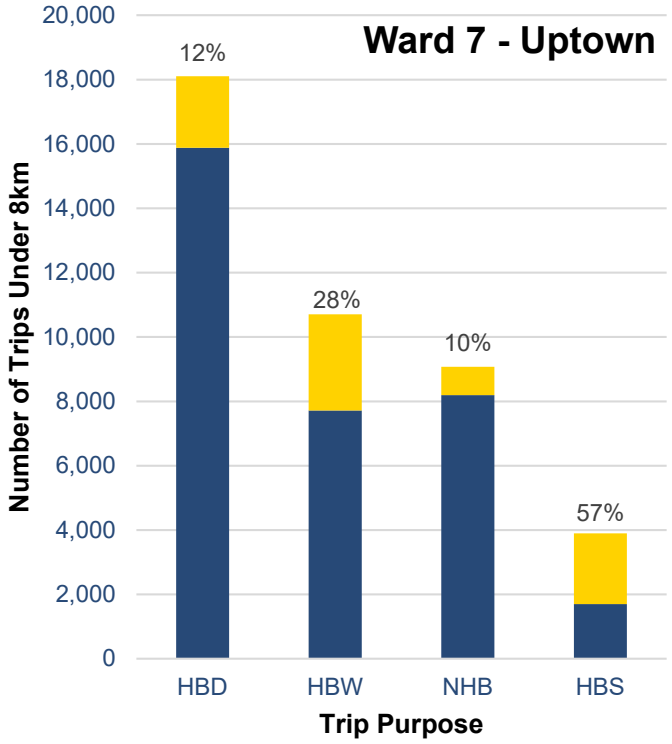


NUMBER OF DAILY TRIPS UNDER 8 KM LONG BY TRIP PURPOSE AND MODE FOR ALL WARDS

Figure 3







Legend

	Walk and Cycle
	Other Modes
HBD	Home Based Discretionary
HBW	Home Based Work
NHB	Non-Home Based
HBS	Home Based School

NUMBER OF DAILY TRIPS UNDER 8 KM LONG BY TRIP PURPOSE AND MODE FOR ALL WARDS

Figure 3 (Continued)

4 Change in Travel Behaviour Between 2011 and 2016

4.1 Socio-Demographic Characteristics

Research has shown that socio-demographic characteristics have a fundamental influence on travel behaviour in communities. Household income has been found to correlate with the number of trips made and vehicle-kilometres travelled. Age and gender are demographic factors that influence trip purpose and the distribution of trip distance. Cultural factors, such as the acceptance of shared mobility modes, are also becoming increasingly relevant for understanding how travel behavior may evolve.[3]

Table 4 details the change in key socio-demographic characteristics observed in the City of Waterloo between 2011 and 2016 based on data from the Statistics Canada Census of Population and Transportation Tomorrow Survey. Note the Census data were not adjusted to account for the reported undercount of population.

The following observations were noted from the data:

- The City's population grew by 6.3% over the five-year period (1.2% per annum). The male population rose at a greater rate (7.4%) than female (5.2%). The median age of Waterloo residents increased only slightly (0.1 years);
- The number of households in Waterloo grew at a faster rate (7.6% or 1.5% per annum) than the City's population between 2011 and 2016. While the proportion of households owning their dwelling did not increase significantly (0.6%), the number of households renting rose considerably (27.2%). Average household size did not change, remaining at 2.6 persons per household, while average total household income (before tax) increased by nearly $8,000. While population and households increased, vehicle ownership decreased (-3.1%); and
- The labour force in Waterloo grew at a slower pace (3.7%) than the City's population between 2011 and 2016, which resulted in a slightly lower participation rate (-2.8%). Employed labour force grew at a faster pace (4.1%) than the total, but still caused a decline in the employment rate (-2.4%). The number of jobs in the City increased (4.8%), resulting in minimal change to the labour force-employment ratio (-1.0%).

Table 5 summarizes the change in population by ward in the City of Waterloo over the five-year 2011 to 2016. Ward 1 – Southeast and Ward 3 – Lakeshore populations decreased by 10% and 24% respectively, while Ward 2 – Northwest and Ward 6 – Central Columbia expanded by approximately 15%. Ward 7 – Uptown experienced the most significant population growth at almost 40%.

[3] U.S. Department of Transportation, Federal Highway Administration. *Understanding Travel Behavior, Research Scan*. March 2016.

Table 4: Change in Socio-Demographic Characteristics, 2011-2016

Indicator		2011	2016	Change
Population	Total	98,780	104,985	+6.3%
	Male	48,870	52,490	+7.4%
	Female	49,910	52,500	+5.2%
	Median Age	37.6 years	37.7 years	+0.1 years
Households	Total	37,515	40,380	+7.6%
	Own	27,625	27,790	+0.6%
	Rent	9,895	12,590	+27.2%
	Average Size	2.6 persons	2.6 persons	0.0 persons
	Average Total Income	$100,414	$108,411	+$7,997
	Average Vehicles	1.63	1.58	-3.1%
Jobs and Labour Force	Total Jobs	63,100	66,100	+4.8%
	Total Labour Force	55,220	57,275	+3.7%
	Employed Labour Force	51,230	53,325	+4.1%
	Participation Rate	68.6%	65.8%	-2.8%
	Employment Rate	63.7%	61.3%	-2.4%
	Labour Force-Employment Ratio	0.88	0.87	-1.0%

Source: 2011 and 2016 Census of Population and 2011 and 2016 Transportation Tomorrow Survey

Table 5: Change in Population by Ward, 2011-2016

Ward	Year		Change	% Change
	2011	2016		
Ward 1 – Southwest	12,400	11,200	-1,200	-10%
Ward 2 – Northwest	14,100	16,100	2,000	14%
Ward 3 – Lakeshore	18,300	13,900	-4,400	-24%
Ward 4 – Northeast	15,400	15,800	400	3%
Ward 5 – Southeast	14,700	15,600	900	6%
Ward 6 – Central-Columbia	12,100	13,900	1,800	15%
Ward 7 – Uptown	11,600	16,000	4,400	38%
City of Waterloo	**98,600**	**102,500[1]**	**3,900**	**4%**

Source: 2011 and 2016 Transportation Tomorrow Survey

Note: 1. Total population reported in **Table 5** differs slightly from the value in **Table 1** due to rounding.

4.2 Daily Trips

During the 2011 to 2016 period, the number of daily trips made by Waterloo residents increased at a greater rate (9.6%) than population growth (6.3%). As illustrated in **Figure 4**, Ward 3 – Lakeshore and Ward 4 – Northeast experienced the largest decline at 9%. The decline in trips made by Ward 3 residents is not surprising given 4,400 fewer people lived in that ward in 2016. Trip making in Ward 1 – Southwest and Ward 5 – Southeast was largely stable. Conversely, Ward 2 – Northwest, Ward 6 – Central-Columbia and Ward 7 – Uptown all experienced significant increases in daily trips made (21%, 9% and 12%, respectively) attributed to population growth in those wards.

4.3 Trip Purpose and Trip Length

Figure 5 shows the change in the number of daily trips by purpose between 2011 and 2016. Only non home-based trips decreased over the five-year period. The growth in home-based discretionary, work and school trips can largely be attributed to the increase in the City's population.

Figure 6 indicates the average trip length has increased for all trip purposes. As a result, the average length of trips originating in the City of Waterloo was 8.7 km in 2016 compared to 8.2 km in 2011.

4.4 Mode Share

Table 6 summarizes the change in mode share between 2011 and 2016. Of note, the auto passenger and driver mode shares decreased by 3% each. This is attributed to the growth in active transportation use, with walking and cycling mode shares increasing by 3% and 2%, respectively.

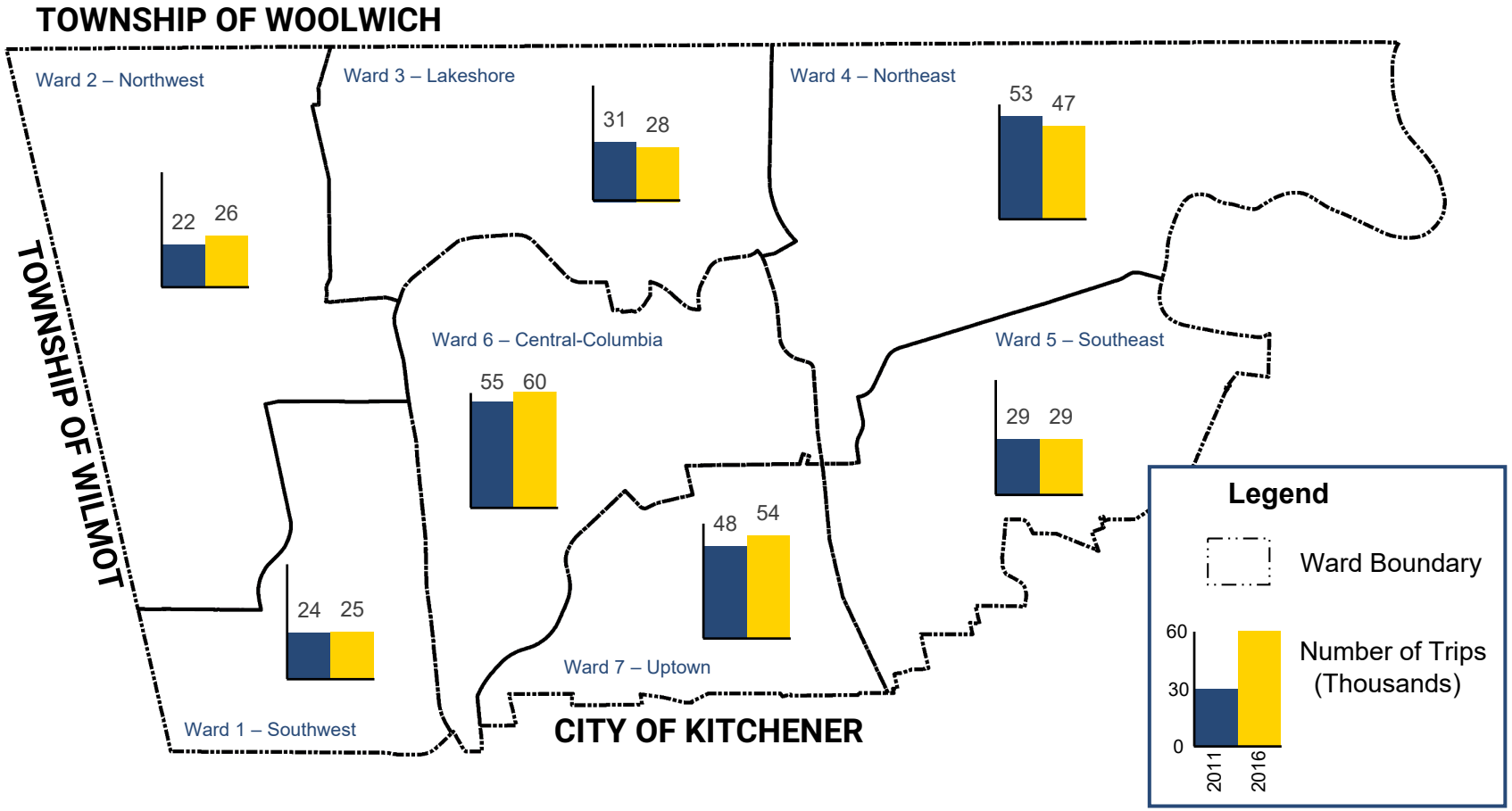
Table 6: Change in Mode Share, 2011-2016

Mode	Year		Change
	2011	2016	
Walk	4%	7%	3%
Cycle	1%	3%	2%
Transit	7%	7%	0%
Auto Passenger	16%	13%	-3%
Auto Driver	70%	67%	-3%
Other	2%	3%	1%

Source: 2011 and 2016 Transportation Tomorrow Survey

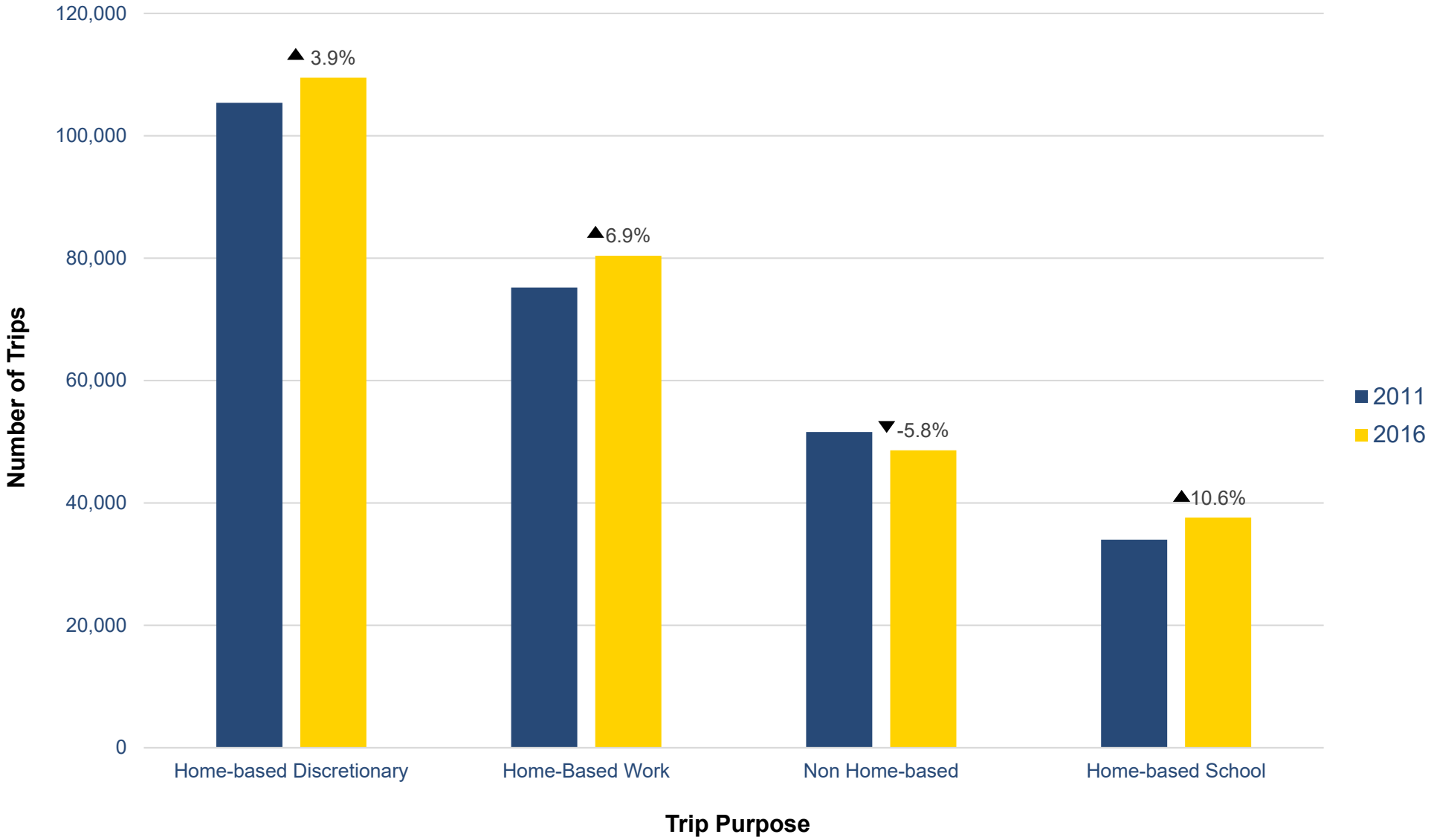
4.5 Mode Share for Trips Within Walking and Cycling Distance

The active transportation mode share of trips less than or equal to 8 km increased in each of the seven wards in the city, except Ward 1 – Southwest, from 2011 to 2016. **Figure 7** shows the percentage of total daily trips within cycling distance for each ward, plus the active transportation (walking and cycling) mode shares. **Figure 8** and **Figure 9** illustrate this data spatially for 2011 and 2016, respectively. The most densely populated central city wards still exhibited the highest active transportation mode share in 2016.



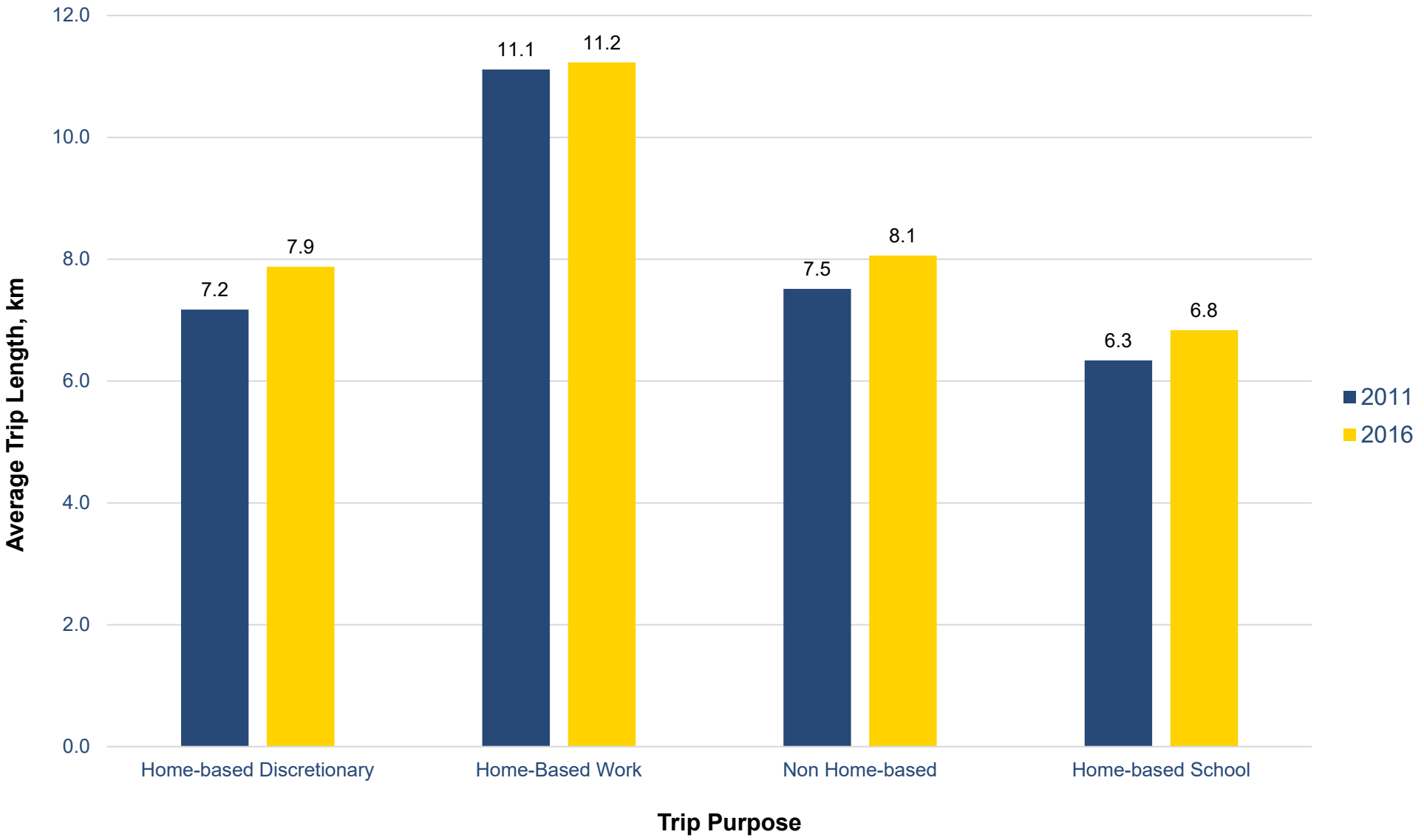
COMPARISON OF TOTAL DAILY TRIPS MADE BY WARD, 2011-2016

Figure 4



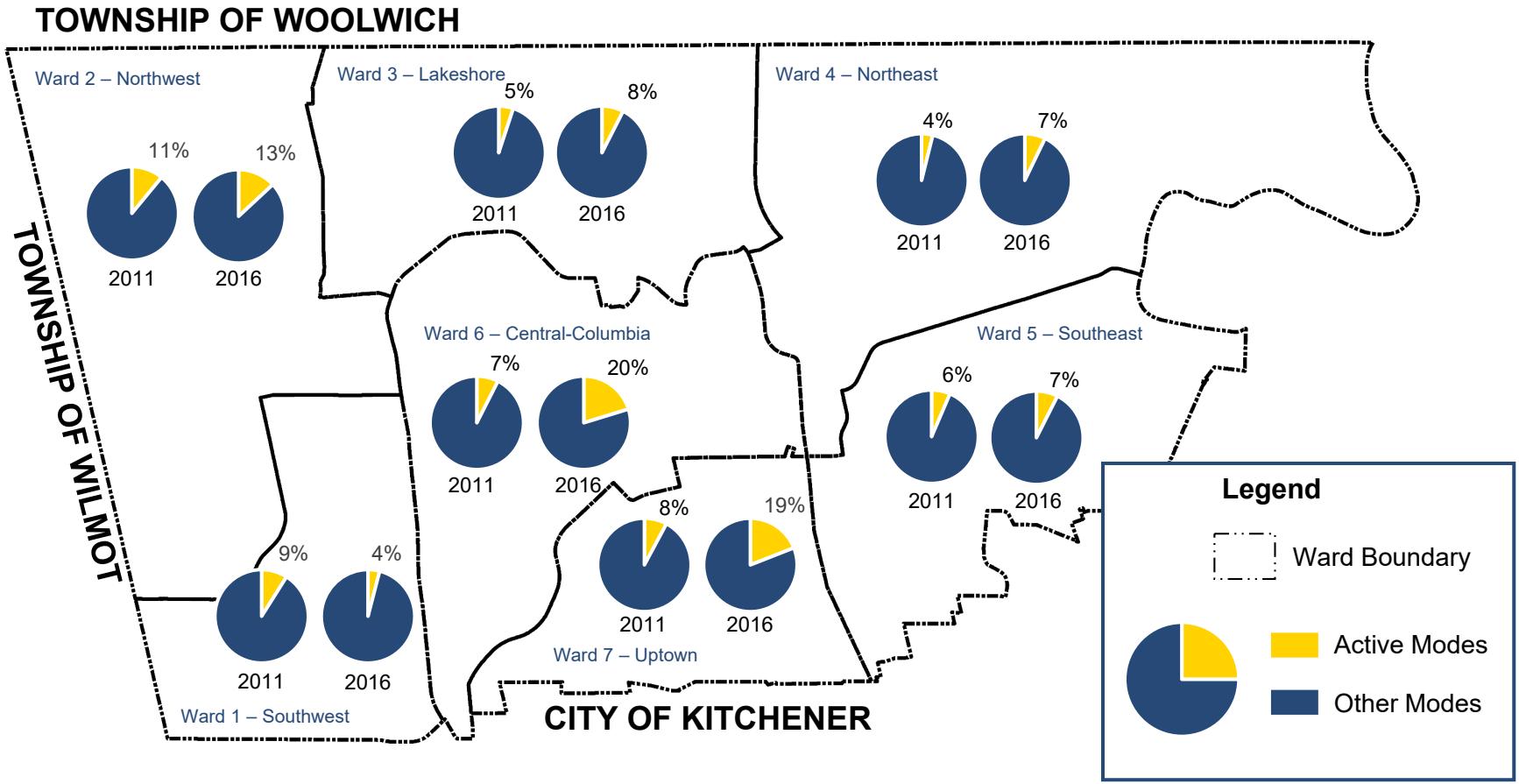
COMPARISON OF TOTAL DAILY TRIPS, 2011-2016

Figure 5



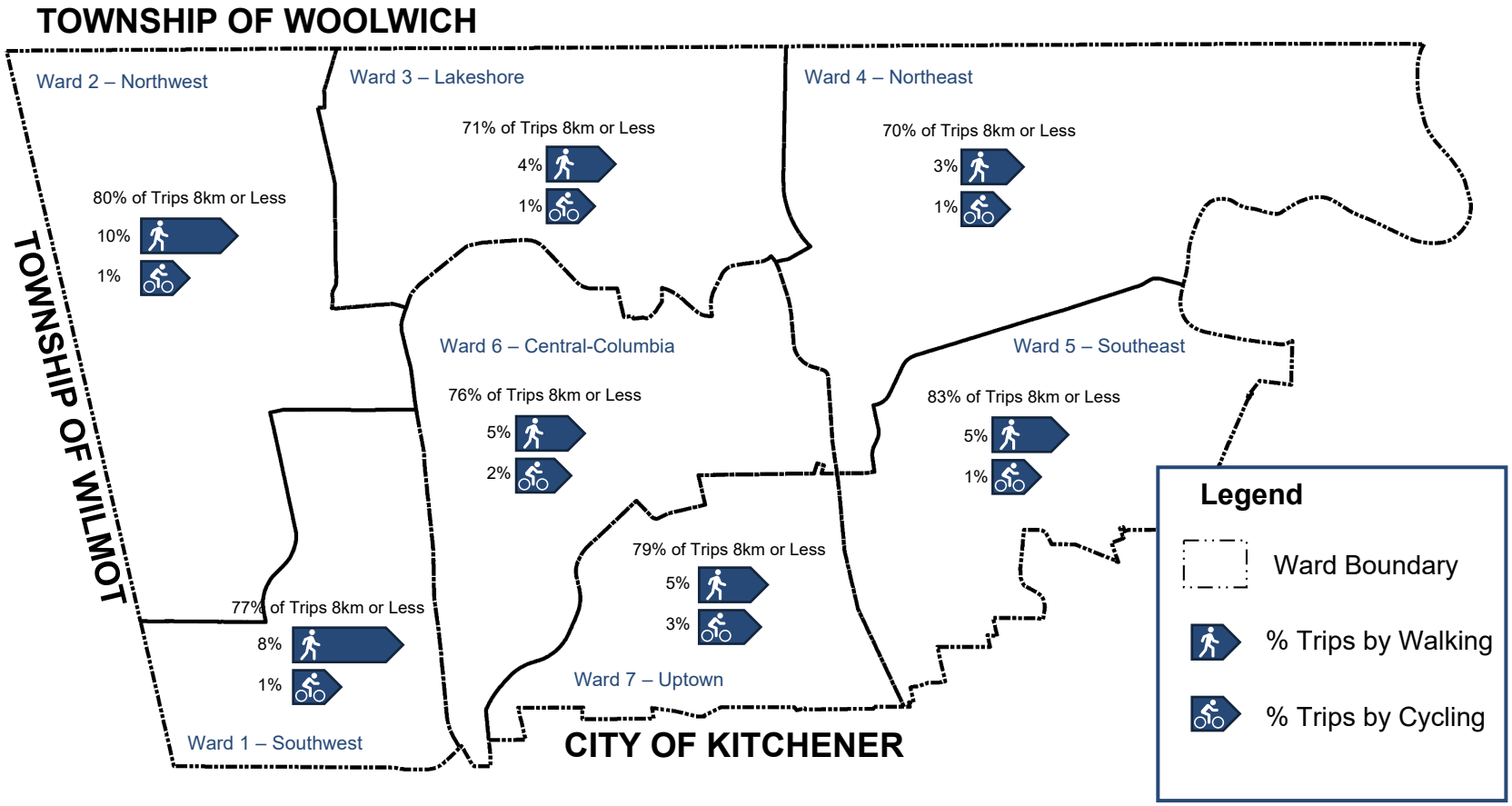
AVERAGE TRIP LENGTH BY TRIP PURPOSE, 2011-2016

Figure 6



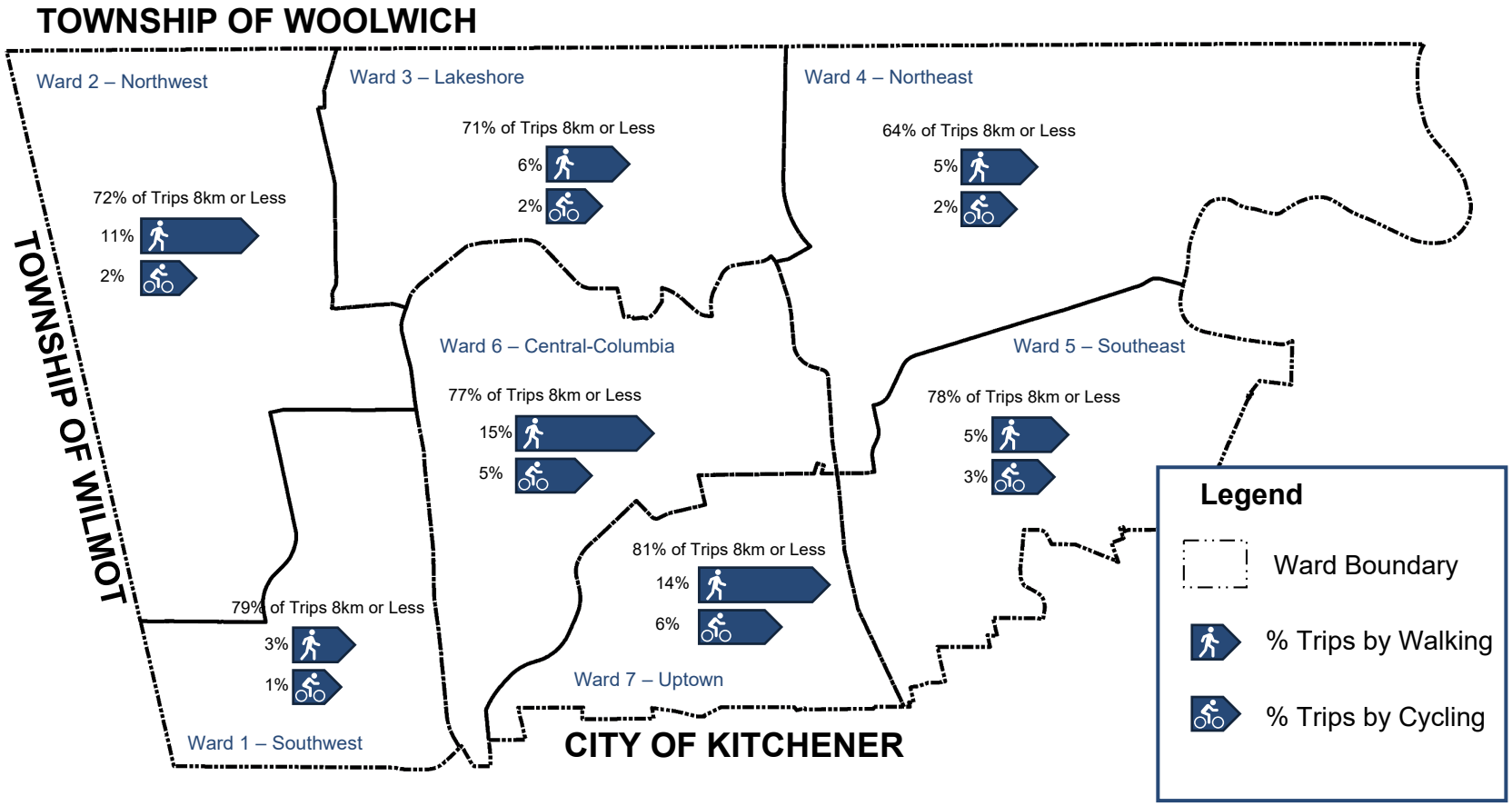
ACTIVE TRANSPORTATION MODE SHARE OF TRIPS 8 KM OR LESS BY WARD, 2011-2016

Figure 7



ACTIVE TRANSPORTATION MODE SHARE OF TRIPS 8 KM OR LESS BY WARD, 2011

Figure 8



ACTIVE TRANSPORTATION MODE SHARE OF TRIPS 8 KM OR LESS BY WARD, 2016

Figure 9

5 Potential Impact of Other Modes on Travel Behaviour

5.1 ION Light Rail Transit

In June 2019, the Region of Waterloo began operating the ION Light Rail Transit (LRT) service between Conestoga Station in Waterloo and Fairway Station in Kitchener, with a total of 19 stations along the route including eight in Waterloo. At Fairway Station, the LRT connects to an express bus service and continues to the Ainslie Street Terminal in Cambridge as a higher-order transit route.

Opening of the ION LRT service is expected to increase transit mode share in the City of Waterloo, as well as active transportation use as more riders are likely to walk or cycle to the stations than drive given their locations and configuration. This effect will be most prevalent in more densely populated Wards 6 and 7, which already exhibit relatively high active transportation and transit mode shares based on the TTS data. Initiatives by the City and Region to improve cycling facilities and provide pedestrian links to the ION LRT stations have helped to remove physical barriers to active transportation access, further spurring travel by these modes. Additionally, Grand River Transit has redesigned its bus network in the City to effectively extend the catchment area of the ION LRT service into Wards 1, 2 and 5. This is expected to increase transit and active transportation use in these wards as well, as riders can easily walk and cycle to nearby bus stops.

By 2021, the next planned iteration of the Transportation Tomorrow Survey, the ION LRT service will be in its third year of operation. Those survey findings will provide a valuable early indication of the impact of the LRT, active transportation enhancements and redesigned bus network on travel behaviour in the city.

5.2 Ridesharing and Shared Mobility

Ridesharing, or shared mobility, is an innovative transportation strategy that enables users to gain short-term access to transportation modes on an as-needed basis. Shared mobility can take various forms such as car-sharing, bike-sharing, carpooling and platform-based ride services (e.g., Uber, Lyft, Bike Share Toronto) and can be broken down into two business models from a commercial perspective:

- **Platform-based ridesharing**, where companies coordinate rides through an online platform such as Uber and Lyft. These services facilitate the peer-to-peer exchange of ride-hailing and may also enable ridesharing and ride-matching.
- **Inventory-based ridesharing**, where companies own assets, like fleets of cars or bikes, that are shared among users. Examples include car2go and Zipcar. Car-sharing offers individuals

who do not own a vehicle a more economical and flexible option (generally) if other modes, such as transit, are not practical for their journey.

Ridesharing is one option for resolving the “last mile” dilemma, capable of serving shorter distance trips to and from a transit station. With ridesharing a viable alternative, individuals may choose to travel by transit for at least a portion of their trip instead of driving the entire route. Used in this manner, ridesharing will increase multi-modal travel while also decreasing the average distance of auto trips.

The advancement of Connected and Autonomous Vehicles (CAVs) may also help to decrease single occupant vehicle (SOV) travel if deployed in a conducive manner. In a “public” system (i.e. CAVs are not owned exclusively by individuals), CAVs could work in collaboration with on-demand services, such as ridesharing and ride-hailing, to provide more mobility options for travelers. However, if CAVs are mostly privately-owned, vehicle volumes are likely to increase leading to more congestion and few overall benefits.

Combining driverless ride-hailing services with the public transit system has the potential to offer a user friendly and cost-effective option for travel to lower density and other underserved locations. This could ultimately reduce SOV trips.

5.3 Bike-Sharing and E-Bikes

Relatively new to North America, public bikeshare systems are rapidly increasing in popularity and changing travel behaviour in communities. A bikeshare is a member-based service that provides short-term, self-serve bicycle rentals on an “as-needed” basis. Typically concentrated in urban environments or major recreational nodes, bike-sharing services enable on-demand one-way or round trips.

The bikeshare operator is typically responsible for bicycle maintenance, storage and parking with costs recovered through user fees. Bike rental charges may be pay-per-use or paid as a monthly/annual membership for unlimited use. With payment arranged, individuals can begin using a bicycle by swiping their credit card or membership card, and/or by mobile phone. When finished the trip, the user returns the bicycle to any dock (one-way trip), the same dock (round-trip service) or anywhere within a geo-fenced location for dockless IT-based bike-sharing systems.

Bike-sharing offers individuals without bicycles the opportunity to cycle. The somewhat universal availability of bicycles in a bikeshare system creates a “network-effect”, encouraging and enabling individuals to cycle for utilitarian purposes (e.g., commuting, errands) who may not otherwise. Having ready access to a bicycle for “first and last mile” trips to public transit and other short distance travel also helps to alleviate the need to drive or use a rideshare service.

Offering electronic bicycles (e-bikes) as part of a bikeshare system provides further benefits to commuters and recreational cyclists. Operating at speeds of up to 45 km/h, e-bikes offer a fast, low cost, energy efficient, and emission-free means of transportation, which also have physical and health benefits for users. Specific benefits of e-bikes include:

- Increased Travel Range – While cycling is generally a viable mode for trips up to 8 km, e-bikes can extend distances up to 24 km;
- Additional Physical Utility – E-bikes have a stable and versatile platform for utility modifications to haul loads and provide options for carrying smaller passengers; and

- Improved Health and Wellness – E-bikes lower the difficulty barrier for people to engage in meaningful, regular exercise and provide seniors another option to extend their period of independence.

A bike-sharing service in the City of Waterloo with both conventional bicycles and e-bikes would provide residents with another viable alternative to the SOV. Given the number of trips in the City under 8 km in length, and the high percentage of those trips currently being made by automobile, the potential exists to grow the share of travel by active modes. The greatest opportunity for a bikeshare system exists in the Uptown area and near the universities.

6 Summary of Key Trends

Comparison of the 2011 and 2016 data indicate:

- Population, housing, and employment in the City of Waterloo increased over this five-year period, while average vehicle ownership decreased;
- The number of daily trips increased at a greater rate than population growth;
- Home-based discretionary, work and school trips increased, while non home-based trips decreased;
- Auto driver and passenger mode shares decreased due to a shift to walking and cycling; and
- Active transportation mode share for trips less than or equal to 8 km increased in each of the seven wards in the City, except Ward 1 – Southwest.

4 INTERSECTION LEVEL OF SERVICE

Technical Memorandum

Date: November 15, 2019

To: Christopher Hodgson, City of Waterloo

From: Gene Chartier, Paradigm Transportation Solutions Limited

c.c.: Kate Whitfield, Alta Planning + Design
Susan Hall, Lura Consulting

Re: **Intersection Level of Service**

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1 Introduction

This memorandum summarizes the analysis of existing operations at major intersections completed as part of the **City of Waterloo Transportation Master Plan (TMP) Update**. The review analyzed the same 47 intersections as the city's 2011 TMP to provide an indication of change over time.

The report is organized as follows:

- Chapter 2 defines the concept of Level of Service and identifies the criteria applied to assess intersection operational efficiency; and
- Chapter 3 presents the analysis approach and findings, denoting locations experiencing "critical" conditions.

2 Level of Service

2.1 Definitions

Level of service (LOS) is a qualitative measure used to describe traffic flow at an intersection. The LOS denotes how well a vehicle movement (or the entire intersection) operates by assigning quality levels based on the delay experienced by drivers. LOS A (best) typifies intersections experiencing short average vehicle delays, whereas LOS F (worst) characterizes extensive vehicular queues and long delays typically associated with high levels of congestion.

In addition to delay, intersection traffic operations are also measured in terms of volume-to-capacity (v/c) ratios. The v/c ratio, also referred to as degree of saturation, represents the sufficiency of an intersection to accommodate the vehicular demand (v) based on the capacity (c), which is defined as the maximum rate at which vehicles can pass through a given point in an hour under prevailing conditions. As the v/c ratio approaches 1.0, traffic flow may become unstable, and delay and queuing

conditions may occur. Once the demand exceeds the capacity (a v/c ratio greater than 1.0), traffic flow is unstable and excessive delay and queuing is expected.

2.2 Signalized Intersections

Signalized intersection LOS is defined in terms of the weighted average control delay for the entire intersection. Control delay quantifies the increase in travel time that a vehicle experiences due to the traffic signal control as well as provides a surrogate measure for driver discomfort and fuel consumption.

LOS for signalized intersections is calculated in terms of average control delay per vehicle (in seconds) during a specified time period (e.g., weekday PM peak hour). Control delay is a complex measure based on many variables, including signal phasing and coordination (i.e. progression of movements through the intersection and along the corridor), signal cycle length, and traffic volumes with respect to intersection capacity and resulting queues. **Table 1** summarizes the LOS criteria for signalized intersections as described in the *Highway Capacity Manual 2010*[1] (HCM).

Table 1: Level of Service Criteria for Signalized Intersections

Level of Service	Average Control Delay (seconds/vehicle)	General Description
A	0 to 10	Free flow
B	> 10 to 20	Stable flow (slight delays)
C	> 20 to 35	Stable flow (acceptable delays)
D	> 35 to 55	Approaching unstable flow (tolerable delay, occasionally wait through more than one signal cycle before proceeding)
E	> 55 to 80	Unstable flow (intolerable delay)
F	> 80	Forced flow (congested and queues fail to clear)

If the v/c ratio for a lane group exceeds 1.0, LOS F is assigned. LOS for the overall approach or intersection is determined solely by the control delay.

2.3 Unsignalized Intersections

Unsignalized intersection LOS criteria are further divided into three types: all-way stop, two-way stop, and roundabout control.

All-way stop and roundabout control intersection LOS is expressed in terms of the weighted average control delay for the overall intersection or by approach. Two-way stop-controlled intersection LOS is defined in terms of the average control delay for each minor-street movement (or shared movement) as well as major street left turns. Since major street through vehicles are assumed to experience zero delay, a weighted average for all movements would result in very low overall average delay for the

[1] *Highway Capacity Manual 2010*, Transportation Research Board, Washington, D.C., 2010

intersection. Assessing operation on this basis could cover deficiencies of minor movements. **Table 2** shows the LOS criteria for unsignalized intersections, as described in the HCM.

Table 2: Level of Service Criteria for Unsignalized Intersections

Level of Service	Average Control Delay (seconds per vehicle)
A	0 to 10
B	> 10 to 15
C	> 15 to 25
D	> 25 to 35
E	> 35 to 50
F	> 50

If the v/c ratio exceeds 1.0, LOS F is assigned to the individual lane group for all unsignalized intersections, or minor street approach at two-way stop-controlled intersections. Overall intersection LOS is determined solely by control delay.

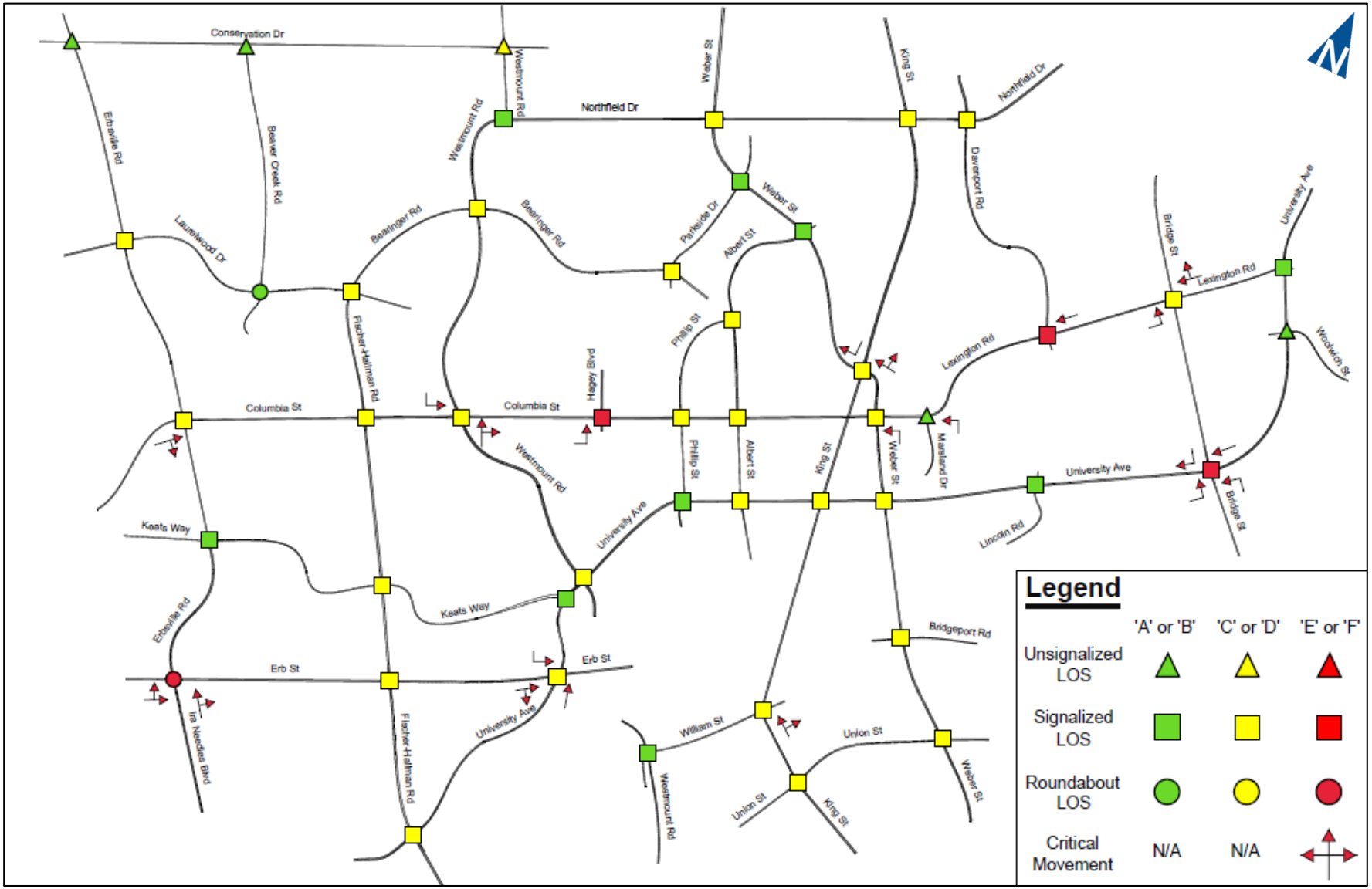
3 Analysis Approach and Findings

3.1 Analysis Approach

Weekday AM and PM peak hour traffic conditions at the 40 signalized, five unsignalized and two roundabout intersections were analyzed using HCM methods captured in Synchro 9 to identify any existing capacity or operational deficiencies. The Region of Waterloo provided base Synchro networks for the analysis, including signal timings and calibrated parameters. The networks were refined as required to reflect current conditions.

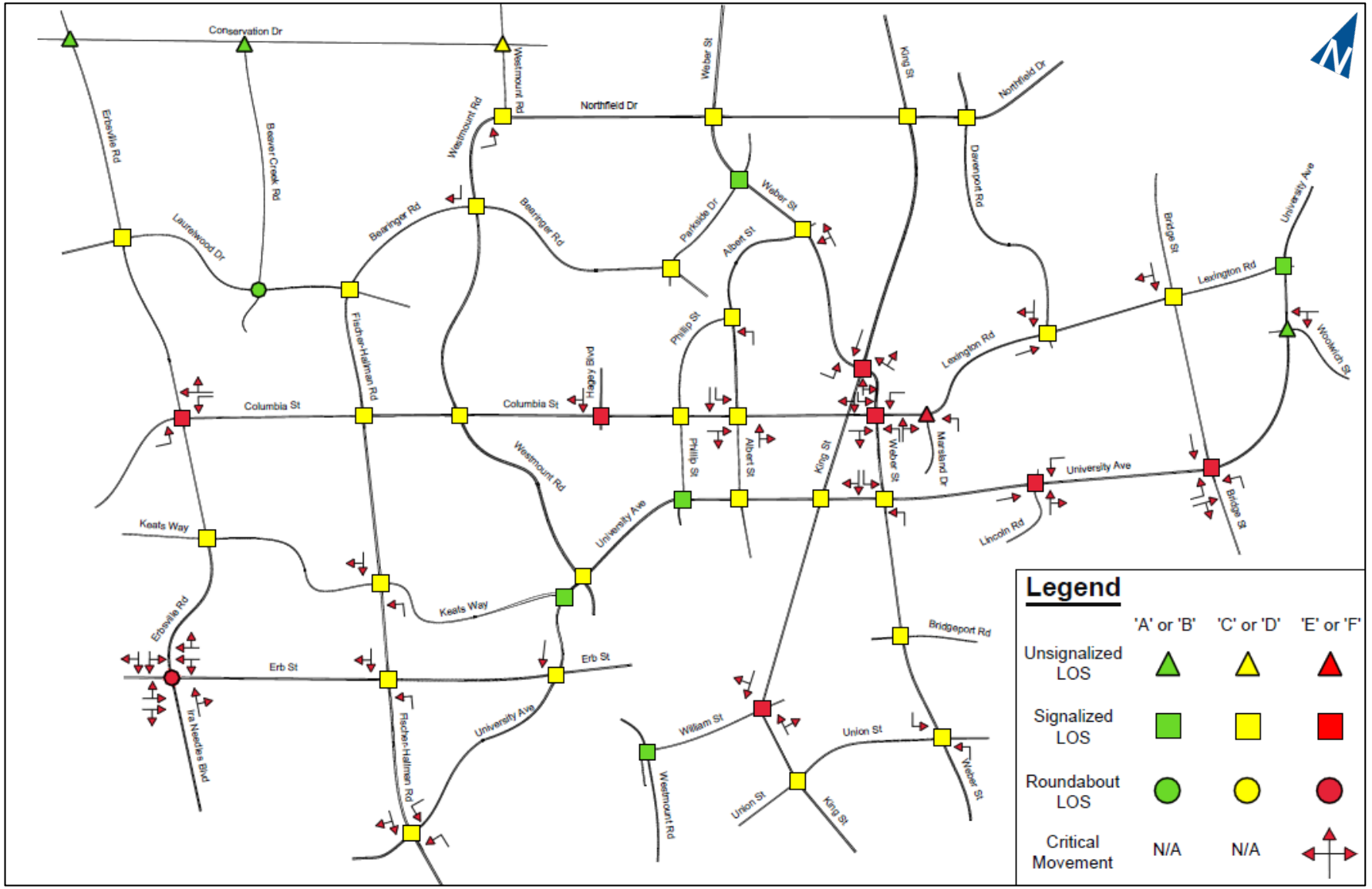
The City of Waterloo and Region of Waterloo provided turning movement counts for the intersections to be analyzed. All counts were recorded between 2015 and 2019 and, if collected prior to 2019, were adjusted to this base year using a 1.4% per annum growth rate. This growth rate was calculated from historical turning movement counts collected in the City of Waterloo between 2010 and 2015.

Figure 1 and **Figure 2** illustrate the LOS results for the analyzed intersections in the weekday AM and PM peak hours, respectively. **Appendix A** and **Appendix B** provide the detailed Synchro analysis output.



EXISTING WEEKDAY AM PEAK HOUR INTERSECTION LEVEL OF SERVICE

Figure 1



EXISTING WEEKDAY PM PEAK HOUR INTERSECTION LEVEL OF SERVICE

Figure 2

3.2 Critical Conditions

For the purpose of this analysis, intersections and/or their individual movements experiencing a LOS E or F and/or a v/c ratio of 0.9 or greater were considered critical. Although a v/c ratio less than 1.0 indicates there is still theoretical capacity for more vehicles to pass through the lane, approach or intersection, applying a v/c ratio of 0.9 captured the intersections and/or individual movements approaching the threshold of their respective theoretical capacities.

Table 3 summarizes the critical movements for the AM peak hour. The 12 intersections that operate or have movements (23 movements) that operate at a critical level are highlighted in red. By comparison, only seven movements at five intersections were considered critical based on the 2008 counts reported in 2011 TMP. Three of these movements still operate at critical levels today, specifically:

- Bridge Street and University Avenue (eastbound left)
- Columbia Street and Erbsville Road (eastbound through-right)
- Columbia Street and Marsland Drive (northbound left)

Table 4 summarizes the critical movements for the PM peak hour. The 23 intersections that operate or have individual movements (56 movements) that operate at a critical level are highlighted in red. By comparison, only nine movements at eight intersection were considered critical based on the 2008 counts reported in 2011 TMP. Four of these movements still operate at critical levels today, specifically:

- Northfield Drive and Westmount Road (eastbound left)
- Albert Street and Columbia Street (northbound through)
- Columbia Street and Marsland Drive (northbound left)
- Lincoln Road and University Avenue (westbound left)

For reference, the afternoon peak hour experiences worse levels of service than the morning due to higher traffic volumes, owing to more discretionary trips being made (i.e. work to home with shopping, recreation, social, etc.).

Table 3: Existing Weekday AM Peak Hour Critical Movements

Intersection	Movement	LOS	v/c Ratio
Signalized Intersections			
Bridge Street and Lexington Road	EBL	F	1.66
	WBTR	F	0.98
Bridge Street and University Avenue	EBL	F	1.01
	WBT	E	0.99
	NBL	E	0.96
	SBR	F	1.06
	Overall	E	-
Columbia Street and Erbsville Road	EBTR	E	0.94
Columbia Street and Hagey Boulevard	EBL	F	1.51
	Overall	E	-
Columbia Street and Weber Street	NBL	F	1.09
Columbia Street and Westmount Road	NBTR	F	0.90
	SBL	E	0.80
Davenport Road and Lexington Road	WBT	F	1.44
	Overall	F	-
Erb Street and University Avenue	NBT	E	0.96
	SBL	E	0.21
	EBTR	E	0.96
King Street and Weber Street	WBTR	E	0.72
	SBR	E	0.73
King Street and William Street	NBTR	D	0.99
Unsignalized Intersections			
Columbia Street and Marsland Drive	NBL	F	1.00
Roundabout Intersections			
Erb Street and Erbsville Road	NWTR	F	1.03
	NELT	E	0.87
	NETR	F	0.92

Table 4: Existing Weekday PM Peak Hour Critical Movements

Intersection	Movement	LOS	v/c Ratio
Signalized Intersections			
Albert Street and Columbia Street	EBTR	E	0.91
	NBTR	E	0.79
	SBL	E	0.86
	SBT	E	0.74
Albert Street and Philip Street	EBL	D	0.92
Albert Street and Weber Street	NBTL	F	1.12
Bearinger Road and Westmount Road	SBR	D	0.95
Bridge Street and Lexington Road	SBTR	D	0.94
Bridge Street and University Avenue	EBL	E	0.95
	EBTR	F	1.17
	NBL	F	1.10
	SBT	E	0.90
	Overall	E	-
Columbia Street and Erbsville Road	EBL	F	0.74
	WBL	F	1.22
	WBTR	E	0.99
	Overall	E	-
Columbia Street and Hagey Boulevard	SBTR	F	1.23
	Overall	E	-
Columbia Street and Weber Street	EBTR	E	0.89
	WBL	E	0.95
	NBL	F	0.97
	NBTR	F	0.94
	SBL	F	1.17
	SBTR	E	0.89
	Overall	E	-
Davenport Road and Lexington Road	EBT	F	1.08
	SBTR	D	0.94
Erb Street and Fischer-Hallman Road	SBTR	E	0.96
	NBL	F	1.04
Erb Street and University Avenue	SBT	D	0.92
Fischer-Hallman Road and Keats Way	NBL	E	0.98
	SBTR	F	1.07
Fischer-Hallman Road and University Avenue	WBL	D	0.90
	NBL	F	1.30
	SBTR	E	0.98

Table 4: Existing Weekday PM Peak Hour Critical Movements

Intersection	Movement	LOS	v/c Ratio
Signalized Intersections			
King Street and Weber Street	EBL	F	1.23
	WBTR	E	0.85
	NBTR	E	0.71
	SBT	E	0.78
	Overall	E	-
King Street and William Street	NBTR	F	1.13
	SBTR	F	1.20
	Overall	E	-
Lincoln Road and University Avenue	EBT	F	1.17
	WBL	E	0.92
	NBTR	F	1.39
	Overall	F	-
Northfield Drive and Westmount Road	EBL	E	0.97
Union Street and Weber Street	NBL	E	0.72
	SBL	E	0.63
University Avenue and Weber Street	SBL	E	0.93
	SBTR	E	0.97
	NBL	E	0.87
Unsignalized Intersections			
Columbia Street and Marsland Drive	NBL	F	17.20
	Overall	F	-
University Avenue and Woolwich Street	WBTL	F	0.86
Roundabout Intersections			
Erb Street and Erbsville Road	SBLT	F	1.06
	SBTR	F	1.21
	NBTR	F	1.46
	EBLT	F	1.01
	EBTR	F	1.07
	WBLT	F	1.41
	WBTR	F	1.46
	Overall	F	-

3.3 Potential Remedial Measures

Remedial measures typically considered to rectify critical intersection conditions include:

- Signal timing adjustments;
- Traffic control changes (e.g., restrict movements, upgrade from stop control to traffic control signals or roundabout); and/or
- Physical improvements (e.g., add left-turn lane, implement channelization).

For signalized intersections, traffic signal timings can be adjusted in some instances to improve LOS for the overall intersections and/or individual movements. Potential measures to optimize intersection capacity include:

- For intersections with actuated left-turn arrows, minimum and maximum feature (arrow) times can be specified in the signal timing plan. If the left-turn movement volume is low and LOS acceptable, the protected left-turn green time could possibly be reduced below the maximum value. Time allocations for other movements may then be increased while still maintaining the original intersection cycle length;
- For intersections with a cross street or side street vehicle phase that can be actuated and/or extended, similar adjustments can be made. If the LOS is acceptable, the green time could possibly be reduced below the maximum value. Time allocations for other movements may then be increased while still maintaining the original intersection cycle length.
- For intersections with protected left-turn phases, the signal operation could be adjusted to allow non-conflicting right-turn movements at the same time as the protected left-turn phase. For example, if the intersection operated with a northbound left-turn protected phase, eastbound right-turn movements may be allowed at the same time. While this action would benefit traffic movement, it would potentially disadvantage pedestrians/ cyclists and introduce undesirable conflicts with vehicles.

Appendix A

AM Peak Hour Traffic Operations Reports

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	206	292	0	0	735	166	0	0	0	136	1	283
Future Volume (veh/h)	206	292	0	0	735	166	0	0	0	136	1	283
Number	5	2	12	1	6	16	3	8	18	7	4	14
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1740	1618	1000	1000	1618	1716	1000	1520	1000	1740	1618	1000
Adj Flow Rate, veh/h	229	324	0	0	817	0	0	0	0	151	1	314
Adj No. of Lanes	1	1	0	0	1	1	0	1	0	1	1	0
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	380	890	0	0	566	510	0	532	0	670	2	480
Arrive On Green	0.17	0.55	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.35	0.35	0.35
Sat Flow, veh/h	1657	1618	0	0	1618	1458	0	1520	0	1657	4	1371
Grp Volume(v), veh/h	229	324	0	0	817	0	0	0	0	151	0	315
Grp Sat Flow(s),veh/h/ln	1657	1618	0	0	1618	1458	0	1520	0	1657	0	1376
Q Serve(g_s), s	5.8	9.0	0.0	0.0	28.0	0.0	0.0	0.0	0.0	5.2	0.0	15.4
Cycle Q Clear(g_c), s	5.8	9.0	0.0	0.0	28.0	0.0	0.0	0.0	0.0	5.2	0.0	15.4
Prop In Lane	1.00		0.00	0.00		1.00	0.00		0.00	1.00		1.00
Lane Grp Cap(c), veh/h	380	890	0	0	566	510	0	532	0	670	0	481
V/C Ratio(X)	0.60	0.36	0.00	0.00	1.44	0.00	0.00	0.00	0.00	0.23	0.00	0.65
Avail Cap(c_a), veh/h	380	890	0	0	566	510	0	532	0	670	0	481
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	15.0	10.1	0.0	0.0	26.0	0.0	0.0	0.0	0.0	18.6	0.0	21.9
Incr Delay (d2), s/veh	6.9	1.2	0.0	0.0	209.2	0.0	0.0	0.0	0.0	0.8	0.0	6.8
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	3.3	4.2	0.0	0.0	45.3	0.0	0.0	0.0	0.0	2.5	0.0	6.8
LnGrp Delay(d),s/veh	21.9	11.3	0.0	0.0	235.2	0.0	0.0	0.0	0.0	19.4	0.0	28.7
LnGrp LOS	C	B			F					B		C
Approach Vol, veh/h		553			817			0			466	
Approach Delay, s/veh		15.7			235.2			0.0			25.7	
Approach LOS		B			F						C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4	5	6		8
Phs Duration (G+Y+Rc), s		48.0		32.0	16.0	32.0		32.0
Change Period (Y+Rc), s		6.0		6.0	4.0	6.0		6.0
Max Green Setting (Gmax), s		42.0		26.0	12.0	26.0		26.0
Max Q Clear Time (g_c+I1), s		11.0		17.4	7.8	30.0		0.0
Green Ext Time (p_c), s		12.0		2.0	0.4	0.0		0.0

Intersection Summary	
HCM 2010 Ctrl Delay	115.9
HCM 2010 LOS	F

Intersection	
Int Delay, s/veh	8.8

Movement	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations						
Traffic Vol, veh/h	524	90	173	959	46	142
Future Vol, veh/h	524	90	173	959	46	142
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	-	-	-	0	0
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	90	90	90	90	90	90
Heavy Vehicles, %	2	2	2	2	2	2
Mvmt Flow	582	100	192	1066	51	158

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	682	0	1549	341
Stage 1	-	-	-	-	632	-
Stage 2	-	-	-	-	917	-
Critical Hdwy	-	-	4.14	-	6.84	6.94
Critical Hdwy Stg 1	-	-	-	-	5.84	-
Critical Hdwy Stg 2	-	-	-	-	5.84	-
Follow-up Hdwy	-	-	2.22	-	3.52	3.32
Pot Cap-1 Maneuver	-	-	907	-	105	655
Stage 1	-	-	-	-	492	-
Stage 2	-	-	-	-	350	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	907	-	~ 51	655
Mov Cap-2 Maneuver	-	-	-	-	~ 51	-
Stage 1	-	-	-	-	492	-
Stage 2	-	-	-	-	168	-

Approach	EB	WB	NB
HCM Control Delay, s	0	3.1	71.5
HCM LOS			F

Minor Lane/Major Mvmt	NBLn1	NBLn2	EBT	EBR	WBL	WBT
Capacity (veh/h)	51	655	-	-	907	-
HCM Lane V/C Ratio	1.002	0.241	-	-	0.212	-
HCM Control Delay (s)	254.5	12.2	-	-	10	1.9
HCM Lane LOS	F	B	-	-	B	A
HCM 95th %tile Q(veh)	4.4	0.9	-	-	0.8	-

Notes			
~: Volume exceeds capacity	$: Delay exceeds 300s	+: Computation Not Defined	*: All major volume in platoon

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	494	894	114	171	300	281	45	90	83	96	106	58
Future Volume (veh/h)	494	894	114	171	300	281	45	90	83	96	106	58
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1740	1740	1000	1740	1740	1000	1740	1863	1716	1740	1740	1000
Adj Flow Rate, veh/h	549	993	127	190	333	312	50	100	92	107	118	64
Adj No. of Lanes	1	2	0	1	2	0	1	1	1	1	2	0
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	365	1147	147	237	643	575	592	724	567	593	824	421
Arrive On Green	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39
Sat Flow, veh/h	731	2950	377	468	1653	1479	1118	1863	1458	1108	2118	1084
Grp Volume(v), veh/h	549	556	564	190	333	312	50	100	92	107	91	91
Grp Sat Flow(s),veh/h/ln	731	1653	1674	468	1653	1479	1118	1863	1458	1108	1653	1549
Q Serve(g_s), s	8.1	11.2	11.2	2.8	5.5	5.9	1.1	1.2	1.5	2.5	1.3	1.4
Cycle Q Clear(g_c), s	14.0	11.2	11.2	14.0	5.5	5.9	2.5	1.2	1.5	3.7	1.3	1.4
Prop In Lane	1.00		0.23	1.00		1.00	1.00		1.00	1.00		0.70
Lane Grp Cap(c), veh/h	365	643	651	237	643	575	592	724	567	593	643	602
V/C Ratio(X)	1.51	0.87	0.87	0.80	0.52	0.54	0.08	0.14	0.16	0.18	0.14	0.15
Avail Cap(c_a), veh/h	365	643	651	237	643	575	592	724	567	593	643	602
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	16.2	10.1	10.1	17.7	8.4	8.5	7.9	7.1	7.2	8.3	7.1	7.1
Incr Delay (d2), s/veh	241.1	14.5	14.4	24.3	3.0	3.6	0.3	0.4	0.6	0.7	0.5	0.5
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	28.0	7.5	7.6	3.4	3.0	2.9	0.4	0.7	0.7	0.9	0.7	0.7
LnGrp Delay(d),s/veh	257.3	24.6	24.6	42.0	11.4	12.2	8.2	7.5	7.8	9.0	7.6	7.7
LnGrp LOS	F	C	C	D	B	B	A	A	A	A	A	A
Approach Vol, veh/h		1669			835			242			289	
Approach Delay, s/veh		101.1			18.6			7.8			8.1	
Approach LOS		F			B			A			A	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		8
Phs Duration (G+Y+Rc), s		18.0		18.0		18.0		18.0
Change Period (Y+Rc), s		6.0		6.0		6.0		6.0
Max Green Setting (Gmax), s		12.0		12.0		12.0		12.0
Max Q Clear Time (g_c+I1), s		4.5		16.0		5.7		16.0
Green Ext Time (p_c), s		2.0		0.0		1.7		0.0

Intersection Summary	
HCM 2010 Ctrl Delay	62.1
HCM 2010 LOS	E

Intersection	
Int Delay, s/veh	6.1

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	6	44	4	94	27	38	1	156	127	57	119	2
Future Vol, veh/h	6	44	4	94	27	38	1	156	127	57	119	2
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Stop	Stop	Stop	Stop	Stop	Stop	Free	Free	Free	Free	Free	Free
RT Channelized	-	-	None	-	-	None	-	-	None	-	-	None
Storage Length	-	-	-	-	-	-	-	-	-	-	-	-
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	90	90	90	90	90	90	90	90	90	90	90	90
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	7	49	4	104	30	42	1	173	141	63	132	2

Major/Minor	Minor2			Minor1			Major1			Major2		
Conflicting Flow All	541	575	133	532	506	244	134	0	0	314	0	0
Stage 1	259	259	-	246	246	-	-	-	-	-	-	-
Stage 2	282	316	-	286	260	-	-	-	-	-	-	-
Critical Hdwy	7.12	6.52	6.22	7.12	6.52	6.22	4.12	-	-	4.12	-	-
Critical Hdwy Stg 1	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Critical Hdwy Stg 2	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Follow-up Hdwy	3.518	4.018	3.318	3.518	4.018	3.318	2.218	-	-	2.218	-	-
Pot Cap-1 Maneuver	452	429	916	458	469	795	1451	-	-	1246	-	-
Stage 1	746	694	-	758	703	-	-	-	-	-	-	-
Stage 2	725	655	-	721	693	-	-	-	-	-	-	-
Platoon blocked, %								-	-		-	-
Mov Cap-1 Maneuver	389	405	916	396	443	795	1451	-	-	1246	-	-
Mov Cap-2 Maneuver	389	405	-	396	443	-	-	-	-	-	-	-
Stage 1	745	656	-	757	702	-	-	-	-	-	-	-
Stage 2	657	654	-	628	655	-	-	-	-	-	-	-

Approach	EB	WB	NB	SB
HCM Control Delay, s	15	17.7	0	2.6
HCM LOS	C	C		

Minor Lane/Major Mvmt	NBL	NBT	NBR	EBLn1	WBLn1	SBL	SBT	SBR
Capacity (veh/h)	1451	-	-	420	459	1246	-	-
HCM Lane V/C Ratio	0.001	-	-	0.143	0.385	0.051	-	-
HCM Control Delay (s)	7.5	0	-	15	17.7	8	0	-
HCM Lane LOS	A	A	-	C	C	A	A	-
HCM 95th %tile Q(veh)	0	-	-	0.5	1.8	0.2	-	-

Intersection	
Int Delay, s/veh	2.9

Movement	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations						
Traffic Vol, veh/h	176	18	66	103	13	58
Future Vol, veh/h	176	18	66	103	13	58
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	-	-	-	0	-
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	90	90	90	90	90	90
Heavy Vehicles, %	2	2	2	2	2	2
Mvmt Flow	196	20	73	114	14	64

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	216	0	466	206
Stage 1	-	-	-	-	206	-
Stage 2	-	-	-	-	260	-
Critical Hdwy	-	-	4.12	-	6.42	6.22
Critical Hdwy Stg 1	-	-	-	-	5.42	-
Critical Hdwy Stg 2	-	-	-	-	5.42	-
Follow-up Hdwy	-	-	2.218	-	3.518	3.318
Pot Cap-1 Maneuver	-	-	1354	-	555	835
Stage 1	-	-	-	-	829	-
Stage 2	-	-	-	-	783	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	1354	-	523	835
Mov Cap-2 Maneuver	-	-	-	-	523	-
Stage 1	-	-	-	-	829	-
Stage 2	-	-	-	-	738	-

Approach	EB	WB	NB
HCM Control Delay, s	0	3.1	10.3
HCM LOS			B

Minor Lane/Major Mvmt	NBLn1	EBT	EBR	WBL	WBT
Capacity (veh/h)	753	-	-	1354	-
HCM Lane V/C Ratio	0.105	-	-	0.054	-
HCM Control Delay (s)	10.3	-	-	7.8	0
HCM Lane LOS	B	-	-	A	A
HCM 95th %tile Q(veh)	0.4	-	-	0.2	-

Intersection	
Intersection Delay, s/veh	12.9
Intersection LOS	B

Approach	EB	WB	NB	SB
Entry Lanes	1	1	1	1
Conflicting Circle Lanes	1	1	1	1
Adj Approach Flow, veh/h	689	272	318	95
Demand Flow Rate, veh/h	703	277	325	96
Vehicles Circulating, veh/h	102	121	667	322
Vehicles Exiting, veh/h	316	871	138	76
Follow-Up Headway, s	3.186	3.186	3.186	3.186
Ped Vol Crossing Leg, #/h	0	0	0	0
Ped Cap Adj	1.000	1.000	1.000	1.000
Approach Delay, s/veh	14.6	6.4	16.9	5.6
Approach LOS	B	A	C	A

Lane	Left	Left	Left	Left
Designated Moves	LTR	LTR	LTR	LTR
Assumed Moves	LTR	LTR	LTR	LTR
RT Channelized				
Lane Util	1.000	1.000	1.000	1.000
Critical Headway, s	5.193	5.193	5.193	5.193
Entry Flow, veh/h	703	277	325	96
Cap Entry Lane, veh/h	1020	1001	580	819
Entry HV Adj Factor	0.981	0.981	0.980	0.985
Flow Entry, veh/h	689	272	318	95
Cap Entry, veh/h	1001	982	568	807
V/C Ratio	0.689	0.277	0.560	0.117
Control Delay, s/veh	14.6	6.4	16.9	5.6
LOS	B	A	C	A
95th %tile Queue, veh	6	1	3	0

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	0	0	0	183	1372	180	184	716	0	0	739	121
Future Volume (veh/h)	0	0	0	183	1372	180	184	716	0	0	739	121
Number				7	4	14	5	2	12	1	6	16
Initial Q (Qb), veh				0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)				1.00		0.99	1.00		1.00	1.00		0.98
Parking Bus, Adj				1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln				1000	1668	1000	1757	1827	0	0	1726	1000
Adj Flow Rate, veh/h				199	1491	196	200	778	0	0	803	132
Adj No. of Lanes				0	4	0	1	2	0	0	2	0
Peak Hour Factor				0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %				0	4	0	1	4	0	0	3	3
Cap, veh/h				231	1865	250	354	1779	0	0	1039	171
Arrive On Green				0.39	0.39	0.39	0.24	1.00	0.00	0.00	0.37	0.37
Sat Flow, veh/h				597	4813	646	1674	3563	0	0	2898	462
Grp Volume(v), veh/h				546	870	470	200	778	0	0	468	467
Grp Sat Flow(s),veh/h/ln				1638	1435	1548	1674	1736	0	0	1639	1634
Q Serve(g_s), s				24.5	21.3	21.3	5.3	0.0	0.0	0.0	20.2	20.2
Cycle Q Clear(g_c), s				24.5	21.3	21.3	5.3	0.0	0.0	0.0	20.2	20.2
Prop In Lane				0.36		0.42	1.00		0.00	0.00		0.28
Lane Grp Cap(c), veh/h				635	1112	600	354	1779	0	0	606	604
V/C Ratio(X)				0.86	0.78	0.78	0.57	0.44	0.00	0.00	0.77	0.77
Avail Cap(c_a), veh/h				635	1112	600	386	1779	0	0	606	604
HCM Platoon Ratio				1.00	1.00	1.00	2.00	2.00	1.00	1.00	1.00	1.00
Upstream Filter(I)				1.00	1.00	1.00	1.00	1.00	0.00	0.00	1.00	1.00
Uniform Delay (d), s/veh				22.5	21.5	21.5	13.2	0.0	0.0	0.0	22.3	22.3
Incr Delay (d2), s/veh				14.2	5.5	9.8	1.6	0.8	0.0	0.0	9.3	9.3
Initial Q Delay(d3),s/veh				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln				13.4	9.2	10.6	2.5	0.2	0.0	0.0	10.7	10.6
LnGrp Delay(d),s/veh				36.7	27.1	31.4	14.8	0.8	0.0	0.0	31.5	31.6
LnGrp LOS				D	C	C	B	A			C	C
Approach Vol, veh/h					1886			978			935	
Approach Delay, s/veh					30.9			3.7			31.5	
Approach LOS					C			A			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4	5	6		
Phs Duration (G+Y+Rc), s		45.0		35.0	11.4	33.6		
Change Period (Y+Rc), s		6.0		6.0	4.0	6.0		
Max Green Setting (Gmax), s		39.0		29.0	9.0	26.0		
Max Q Clear Time (g_c+I1), s		2.0		26.5	7.3	22.2		
Green Ext Time (p_c), s		19.7		2.3	0.1	3.3		

Intersection Summary	
HCM 2010 Ctrl Delay	24.1
HCM 2010 LOS	C

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	110	249	103	33	448	40	121	680	30	39	653	194
Future Volume (veh/h)	110	249	103	33	448	40	121	680	30	39	653	194
Number	3	8	18	7	4	14	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.99	1.00		0.99	1.00		0.99	1.00		0.99
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1000	1625	1000	1000	1618	1000	1757	1623	1000	1557	1630	1000
Adj Flow Rate, veh/h	122	277	114	37	498	44	134	756	33	43	726	216
Adj No. of Lanes	0	2	0	0	2	0	1	2	0	1	2	0
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	2	2	2	1	1	1	1	1	1	14	1	1
Cap, veh/h	195	466	215	86	949	87	376	1542	67	289	1204	358
Arrive On Green	0.13	0.13	0.13	0.39	0.39	0.39	0.51	0.51	0.51	1.00	1.00	1.00
Sat Flow, veh/h	325	1203	555	91	2450	224	558	3008	131	571	2350	699
Grp Volume(v), veh/h	231	0	282	297	0	282	134	387	402	43	478	464
Grp Sat Flow(s),veh/h/ln	708	0	1376	1334	0	1431	558	1542	1598	571	1548	1501
Q Serve(g_s), s	15.2	0.0	15.4	1.0	0.0	12.0	12.3	13.1	13.1	2.3	0.0	0.0
Cycle Q Clear(g_c), s	27.2	0.0	15.4	16.4	0.0	12.0	12.3	13.1	13.1	15.4	0.0	0.0
Prop In Lane	0.53		0.40	0.12		0.16	1.00		0.08	1.00		0.47
Lane Grp Cap(c), veh/h	343	0	533	567	0	555	376	790	819	289	794	769
V/C Ratio(X)	0.67	0.00	0.53	0.52	0.00	0.51	0.36	0.49	0.49	0.15	0.60	0.60
Avail Cap(c_a), veh/h	343	0	533	567	0	555	376	790	819	289	794	769
HCM Platoon Ratio	0.33	0.33	0.33	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00	2.00
Upstream Filter(I)	1.00	0.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	36.2	0.0	28.1	18.5	0.0	18.7	12.5	12.7	12.7	2.5	0.0	0.0
Incr Delay (d2), s/veh	10.1	0.0	3.7	3.4	0.0	3.3	2.6	2.2	2.1	1.1	3.4	3.5
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	6.0	0.0	6.4	5.4	0.0	5.2	2.2	6.0	6.2	0.4	0.7	0.7
LnGrp Delay(d),s/veh	46.3	0.0	31.8	21.9	0.0	22.0	15.1	14.9	14.8	3.5	3.4	3.5
LnGrp LOS	D		C	C		C	B	B	B	A	A	A
Approach Vol, veh/h		513			579			923			985	
Approach Delay, s/veh		38.3			22.0			14.9			3.4	
Approach LOS		D			C			B			A	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		8
Phs Duration (G+Y+Rc), s		45.0		35.0		45.0		35.0
Change Period (Y+Rc), s		6.0		6.0		6.0		6.0
Max Green Setting (Gmax), s		39.0		29.0		39.0		29.0
Max Q Clear Time (g_c+I1), s		15.1		18.4		17.4		29.2
Green Ext Time (p_c), s		16.9		5.8		15.7		0.0

Intersection Summary	
HCM 2010 Ctrl Delay	16.5
HCM 2010 LOS	B

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	161	301	26	132	75	17	15	514	147	7	540	41
Future Volume (veh/h)	161	301	26	132	75	17	15	514	147	7	540	41
Number	3	8	18	7	4	14	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	0.99		0.98	1.00		0.98	1.00		0.97	1.00		0.96
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1757	1645	1000	1775	1632	1000	1659	1550	1000	1775	1560	1000
Adj Flow Rate, veh/h	179	334	29	147	83	19	17	571	163	8	600	46
Adj No. of Lanes	1	1	0	1	1	0	1	1	0	1	1	0
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	1	0	0	0	0	0	7	8	8	0	6	6
Cap, veh/h	519	596	52	308	512	117	121	575	164	95	614	47
Arrive On Green	0.40	0.40	0.38	0.40	0.40	0.38	0.02	0.50	0.47	0.43	0.43	0.41
Sat Flow, veh/h	1198	1489	129	964	1280	293	1580	1151	329	686	1426	109
Grp Volume(v), veh/h	179	0	363	147	0	102	17	0	734	8	0	646
Grp Sat Flow(s),veh/h/ln	1198	0	1619	964	0	1573	1580	0	1480	686	0	1536
Q Serve(g_s), s	9.0	0.0	13.9	11.1	0.0	3.4	0.5	0.0	39.4	0.6	0.0	33.1
Cycle Q Clear(g_c), s	12.4	0.0	13.9	25.0	0.0	3.4	0.5	0.0	39.4	34.4	0.0	33.1
Prop In Lane	1.00		0.08	1.00		0.19	1.00		0.22	1.00		0.07
Lane Grp Cap(c), veh/h	519	0	647	308	0	629	121	0	740	95	0	661
V/C Ratio(X)	0.34	0.00	0.56	0.48	0.00	0.16	0.14	0.00	0.99	0.08	0.00	0.98
Avail Cap(c_a), veh/h	519	0	647	308	0	629	208	0	740	95	0	661
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	19.4	0.0	18.6	28.3	0.0	15.5	19.6	0.0	20.1	39.8	0.0	22.5
Incr Delay (d2), s/veh	1.8	0.0	3.5	5.2	0.0	0.6	0.5	0.0	31.3	1.7	0.0	29.9
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	8.2	0.0	6.8	3.4	0.0	1.6	0.2	0.0	22.3	0.2	0.0	19.3
LnGrp Delay(d),s/veh	21.2	0.0	22.1	33.5	0.0	16.1	20.2	0.0	51.3	41.5	0.0	52.4
LnGrp LOS	C		C	C		B	C		D	D		D
Approach Vol, veh/h		542			249			751			654	
Approach Delay, s/veh		21.8			26.3			50.6			52.3	
Approach LOS		C			C			D			D	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4	5	6		8
Phs Duration (G+Y+Rc), s		44.0		36.0	5.6	38.4		36.0
Change Period (Y+Rc), s		6.0		6.0	4.0	6.0		6.0
Max Green Setting (Gmax), s		38.0		30.0	6.0	28.0		30.0
Max Q Clear Time (g_c+I1), s		41.4		27.0	2.5	36.4		15.9
Green Ext Time (p_c), s		0.0		1.5	0.0	0.0		4.6

Intersection Summary	
HCM 2010 Ctrl Delay	41.3
HCM 2010 LOS	D

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	39	441	44	110	498	74	0	184	72	3	177	45
Future Volume (veh/h)	39	441	44	110	498	74	0	184	72	3	177	45
Number	3	8	18	7	4	14	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.94	1.00		1.00	1.00		0.95	0.98		0.97
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1723	1618	1000	1757	1845	1667	1707	1681	1000	1723	1681	1000
Adj Flow Rate, veh/h	39	441	44	110	498	0	0	184	72	3	177	45
Adj No. of Lanes	1	1	0	1	1	1	1	2	0	1	2	0
Peak Hour Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Percent Heavy Veh, %	3	2	2	1	3	5	4	7	7	3	6	6
Cap, veh/h	231	611	61	235	784	602	511	943	352	442	1199	296
Arrive On Green	0.43	0.43	0.40	0.14	0.14	0.00	0.00	0.42	0.40	0.01	0.95	0.90
Sat Flow, veh/h	828	1438	143	853	1845	1417	1625	2241	837	1641	2525	623
Grp Volume(v), veh/h	39	0	485	110	498	0	0	129	127	3	110	112
Grp Sat Flow(s),veh/h/ln	828	0	1581	853	1845	1417	1625	1597	1481	1641	1597	1551
Q Serve(g_s), s	3.3	0.0	20.4	10.2	20.4	0.0	0.0	4.1	4.5	0.1	0.3	0.5
Cycle Q Clear(g_c), s	23.7	0.0	20.4	30.6	20.4	0.0	0.0	4.1	4.5	0.1	0.3	0.5
Prop In Lane	1.00		0.09	1.00		1.00	1.00		0.56	1.00		0.40
Lane Grp Cap(c), veh/h	231	0	672	235	784	602	511	672	623	442	759	737
V/C Ratio(X)	0.17	0.00	0.72	0.47	0.64	0.00	0.00	0.19	0.20	0.01	0.15	0.15
Avail Cap(c_a), veh/h	231	0	672	235	784	602	610	672	623	538	759	737
HCM Platoon Ratio	1.00	1.00	1.00	0.33	0.33	0.33	1.00	1.00	1.00	2.00	2.00	2.00
Upstream Filter(I)	1.00	0.00	1.00	1.00	1.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	28.9	0.0	19.2	43.0	28.5	0.0	0.0	14.6	15.1	13.5	1.1	1.5
Incr Delay (d2), s/veh	1.6	0.0	6.6	6.5	3.9	0.0	0.0	0.6	0.7	0.0	0.4	0.4
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.8	0.0	10.0	2.8	11.3	0.0	0.0	1.9	1.9	0.0	0.2	0.3
LnGrp Delay(d),s/veh	30.5	0.0	25.8	49.5	32.4	0.0	0.0	15.2	15.8	13.5	1.5	1.9
LnGrp LOS	C		C	D	C			B	B	B	A	A
Approach Vol, veh/h		524			608			256			225	
Approach Delay, s/veh		26.1			35.5			15.5			1.9	
Approach LOS		C			D			B			A	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4	5	6		8
Phs Duration (G+Y+Rc), s	4.3	37.7		38.0	0.0	42.0		38.0
Change Period (Y+Rc), s	4.0	6.0		6.0	4.0	6.0		6.0
Max Green Setting (Gmax), s	5.3	27.0		32.0	5.0	27.0		32.0
Max Q Clear Time (g_c+I1), s	2.1	6.5		32.6	0.0	2.5		25.7
Green Ext Time (p_c), s	0.0	3.4		0.0	0.0	3.6		4.0

Intersection Summary	
HCM 2010 Ctrl Delay	24.6
HCM 2010 LOS	C

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	146	10	96	1	1	0	192	375	16	8	433	136
Future Volume (veh/h)	146	10	96	1	1	0	192	375	16	8	433	136
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1000	1619	980	1775	1650	1000	1000	1604	1000	1000	1618	1000
Adj Flow Rate, veh/h	162	10	96	1	1	0	192	417	16	9	481	151
Adj No. of Lanes	0	1	1	1	1	0	0	2	0	0	2	0
Peak Hour Factor	0.90	1.00	1.00	1.00	1.00	0.90	1.00	0.90	1.00	0.90	0.90	0.90
Percent Heavy Veh, %	0	0	2	0	0	0	2	2	2	2	2	2
Cap, veh/h	519	29	308	419	610	0	395	843	33	53	1191	367
Arrive On Green	0.37	0.37	0.00	0.37	0.37	0.00	0.00	0.53	0.53	1.00	1.00	1.00
Sat Flow, veh/h	1166	79	833	1222	1650	0	595	1590	62	13	2248	693
Grp Volume(v), veh/h	172	0	96	1	1	0	250	0	375	347	0	294
Grp Sat Flow(s),veh/h/ln	1244	0	833	1222	1650	0	798	0	1449	1605	0	1350
Q Serve(g_s), s	7.9	0.0	9.2	0.0	0.0	0.0	22.8	0.0	13.1	0.0	0.0	0.0
Cycle Q Clear(g_c), s	8.1	0.0	9.2	8.1	0.0	0.0	23.4	0.0	13.1	0.0	0.0	0.0
Prop In Lane	0.94		1.00	1.00		0.00	0.77		0.04	0.03		0.51
Lane Grp Cap(c), veh/h	548	0	308	419	610	0	503	0	768	897	0	715
V/C Ratio(X)	0.31	0.00	0.31	0.00	0.00	0.00	0.50	0.00	0.49	0.39	0.00	0.41
Avail Cap(c_a), veh/h	548	0	308	419	611	0	503	0	768	897	0	715
HCM Platoon Ratio	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00	1.00	2.00	2.00	2.00
Upstream Filter(I)	1.00	0.00	1.00	1.00	1.00	0.00	1.00	0.00	1.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	18.4	0.0	29.8	21.4	15.9	0.0	26.5	0.0	11.9	0.0	0.0	0.0
Incr Delay (d2), s/veh	1.5	0.0	2.6	0.0	0.0	0.0	3.5	0.0	2.2	1.3	0.0	1.7
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	3.0	0.0	2.4	0.0	0.0	0.0	5.7	0.0	5.7	0.3	0.0	0.3
LnGrp Delay(d),s/veh	19.9	0.0	32.4	21.4	15.9	0.0	30.0	0.0	14.1	1.3	0.0	1.7
LnGrp LOS	B		C	C	B		C		B	A		A
Approach Vol, veh/h		268			2			625			641	
Approach Delay, s/veh		24.4			18.6			20.5			1.5	
Approach LOS		C			B			C			A	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		8
Phs Duration (G+Y+Rc), s		46.4		33.6		46.4		33.6
Change Period (Y+Rc), s		6.0		6.0		6.0		6.0
Max Green Setting (Gmax), s		40.4		27.6		30.0		27.6
Max Q Clear Time (g_c+I1), s		25.4		11.2		2.0		10.1
Green Ext Time (p_c), s		8.5		1.4		12.2		1.5

Intersection Summary	
HCM 2010 Ctrl Delay	13.2
HCM 2010 LOS	B

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	205	342	174	45	463	230	94	468	31	128	585	362
Future Volume (veh/h)	205	342	174	45	463	230	94	468	31	128	585	362
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.99	0.99		0.98	1.00		0.99	1.00		0.99
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1740	1718	1000	1614	1718	1000	1707	1696	1000	1740	1827	1716
Adj Flow Rate, veh/h	223	372	189	49	503	250	102	509	34	139	636	393
Adj No. of Lanes	1	2	0	1	2	0	1	2	0	1	2	1
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	10	3	3	4	5	5	2	4	2
Cap, veh/h	270	823	411	261	702	347	243	1088	73	322	1284	536
Arrive On Green	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sat Flow, veh/h	1657	2099	1049	1537	2105	1041	1625	3064	204	1657	3471	1449
Grp Volume(v), veh/h	223	288	273	49	389	364	102	267	276	139	636	393
Grp Sat Flow(s),veh/h/ln	1657	1632	1516	1537	1632	1515	1625	1611	1658	1657	1736	1449
Q Serve(g_s), s	9.4	19.4	19.8	2.4	26.2	26.4	4.4	18.2	18.3	5.9	20.2	29.8
Cycle Q Clear(g_c), s	9.4	19.4	19.8	2.4	26.2	26.4	4.4	18.2	18.3	5.9	20.2	29.8
Prop In Lane	1.00		0.69	1.00		0.69	1.00		0.12	1.00		1.00
Lane Grp Cap(c), veh/h	270	640	594	261	544	505	243	572	589	322	1284	536
V/C Ratio(X)	0.82	0.45	0.46	0.19	0.72	0.72	0.42	0.47	0.47	0.43	0.50	0.73
Avail Cap(c_a), veh/h	270	640	594	350	544	505	334	572	589	390	1284	536
HCM Platoon Ratio	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	28.7	43.1	43.4	25.7	49.8	49.9	25.0	44.6	44.6	24.6	44.7	49.6
Incr Delay (d2), s/veh	18.4	2.3	2.5	0.3	7.8	8.6	1.2	2.7	2.7	0.9	1.4	8.6
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	8.8	0.4	0.4	0.2	1.2	1.2	0.8	0.4	0.4	1.0	10.0	1.3
LnGrp Delay(d),s/veh	47.1	45.4	45.9	26.1	57.6	58.4	26.1	47.3	47.3	25.5	46.1	58.2
LnGrp LOS	D	D	D	C	E	E	C	D	D	C	D	E
Approach Vol, veh/h		784			802			645			1168	
Approach Delay, s/veh		46.1			56.0			44.0			47.7	
Approach LOS		D			E			D			D	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	11.9	43.1	7.9	47.1	10.3	44.7	14.3	40.7
Change Period (Y+Rc), s	4.0	6.0	4.0	6.0	4.0	6.0	4.0	6.0
Max Green Setting (Gmax), s	12.5	32.5	10.3	34.7	12.5	32.5	10.3	34.7
Max Q Clear Time (g_c+I1), s	7.9	20.3	4.4	21.8	6.4	31.8	11.4	28.4
Green Ext Time (p_c), s	0.2	8.1	0.0	7.5	0.2	0.6	0.0	4.3

Intersection Summary	
HCM 2010 Ctrl Delay	48.6
HCM 2010 LOS	D

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	93	719	98	93	804	49	101	104	53	14	75	49
Future Volume (veh/h)	93	719	98	93	804	49	101	104	53	14	75	49
Number	1	6	16	5	2	12	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.73	1.00		0.74	0.95		0.94	0.93		0.92
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1757	1717	1000	1757	1679	1000	1628	1618	1000	1775	1881	1549
Adj Flow Rate, veh/h	101	782	107	101	874	53	110	113	58	15	82	53
Adj No. of Lanes	1	2	0	1	2	0	1	1	0	1	1	1
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	1	3	3	1	6	6	9	3	3	0	1	13
Cap, veh/h	235	1226	168	245	1340	81	394	374	192	336	508	421
Arrive On Green	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sat Flow, veh/h	1674	2747	376	1674	2985	181	1551	984	505	1077	1881	1214
Grp Volume(v), veh/h	101	464	425	101	467	460	110	0	171	15	82	53
Grp Sat Flow(s),veh/h/ln	1674	1631	1492	1674	1595	1571	1551	0	1488	1077	1881	1214
Q Serve(g_s), s	3.3	28.5	28.5	3.3	29.3	29.3	5.0	0.0	11.5	1.4	4.4	3.9
Cycle Q Clear(g_c), s	3.3	28.5	28.5	3.3	29.3	29.3	5.0	0.0	11.5	1.9	4.4	3.9
Prop In Lane	1.00		0.25	1.00		0.12	1.00		0.34	1.00		1.00
Lane Grp Cap(c), veh/h	235	728	666	245	716	705	394	0	566	336	508	421
V/C Ratio(X)	0.43	0.64	0.64	0.41	0.65	0.65	0.28	0.00	0.30	0.04	0.16	0.13
Avail Cap(c_a), veh/h	317	728	666	272	716	705	394	0	566	336	508	421
HCM Platoon Ratio	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	20.8	41.9	41.9	20.4	42.2	42.2	25.5	0.0	36.7	38.7	38.7	31.5
Incr Delay (d2), s/veh	1.2	4.2	4.6	1.1	4.6	4.6	0.4	0.0	1.4	0.3	0.7	0.6
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	1.1	0.9	0.9	1.1	0.9	0.9	0.3	0.0	0.2	0.4	0.1	1.4
LnGrp Delay(d),s/veh	22.0	46.1	46.6	21.5	46.8	46.8	25.8	0.0	38.1	38.9	39.4	32.1
LnGrp LOS	C	D	D	C	D	D	C		D	D	D	C
Approach Vol, veh/h		990			1028			281			150	
Approach Delay, s/veh		43.9			44.3			33.3			36.8	
Approach LOS		D			D			C			D	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4	5	6	7	8
Phs Duration (G+Y+Rc), s	9.1	48.9		42.0	9.4	48.6	11.0	31.0
Change Period (Y+Rc), s	4.0	6.0		6.0	4.0	6.0	4.0	6.0
Max Green Setting (Gmax), s	10.0	38.0		36.0	7.0	41.0	7.0	25.0
Max Q Clear Time (g_c+I1), s	5.3	31.3		13.5	5.3	30.5	7.0	6.4
Green Ext Time (p_c), s	0.1	5.6		2.1	0.0	8.3	0.0	2.0

Intersection Summary	
HCM 2010 Ctrl Delay	42.4
HCM 2010 LOS	D

Movement	EBL	EBR	NBL	NBT	SBT	SBR
Lane Configurations						
Traffic Volume (veh/h)	59	61	148	173	244	270
Future Volume (veh/h)	59	61	148	173	244	270
Number	7	14	5	2	6	16
Initial Q (Qb), veh	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00	1.00	1.00			1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1599	1716	1000	1576	1570	1000
Adj Flow Rate, veh/h	59	61	148	173	244	270
Adj No. of Lanes	1	1	0	2	2	0
Peak Hour Factor	1.00	1.00	1.00	1.00	1.00	1.00
Percent Heavy Veh, %	11	2	7	7	3	3
Cap, veh/h	85	81	476	980	1073	960
Arrive On Green	0.00	0.00	0.00	0.00	0.00	0.00
Sat Flow, veh/h	1523	1458	537	1434	1570	1334
Grp Volume(v), veh/h	59	61	148	173	244	270
Grp Sat Flow(s),veh/h/ln	1523	1458	537	1362	1491	1334
Q Serve(g_s), s	3.1	3.3	15.8	10.2	13.1	16.2
Cycle Q Clear(g_c), s	3.1	3.3	32.0	10.2	13.1	16.2
Prop In Lane	1.00	1.00	1.00			1.00
Lane Grp Cap(c), veh/h	85	81	476	980	1073	960
V/C Ratio(X)	0.70	0.75	0.31	0.18	0.23	0.28
Avail Cap(c_a), veh/h	438	419	476	980	1073	960
HCM Platoon Ratio	0.00	0.00	0.00	0.00	0.00	0.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	39.3	39.5	35.3	16.3	17.8	19.3
Incr Delay (d2), s/veh	9.9	13.1	1.7	0.4	0.5	0.7
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.2	0.3	0.2	0.1	0.1	0.2
LnGrp Delay(d),s/veh	49.2	52.5	37.0	16.7	18.3	20.0
LnGrp LOS	D	D	D	B	B	C
Approach Vol, veh/h	120			321	514	
Approach Delay, s/veh	50.9			26.1	19.2	
Approach LOS	D			C	B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		
Phs Duration (G+Y+Rc), s		66.6		13.4		66.6		
Change Period (Y+Rc), s		6.0		6.0		6.0		
Max Green Setting (Gmax), s		42.0		26.0		42.0		
Max Q Clear Time (g_c+I1), s		34.0		5.3		18.2		
Green Ext Time (p_c), s		3.8		0.4		7.2		

Intersection Summary	
HCM 2010 Ctrl Delay	25.5
HCM 2010 LOS	C

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	49	668	72	76	945	140	157	192	41	96	201	42
Future Volume (veh/h)	49	668	72	76	945	140	157	192	41	96	201	42
Number	1	6	16	5	2	12	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.93	1.00		0.96	0.98		0.96	0.98		0.97
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1775	1692	1000	1723	1709	1000	1757	1615	1000	1723	1827	1750
Adj Flow Rate, veh/h	53	726	78	83	1027	152	171	209	45	104	218	46
Adj No. of Lanes	1	2	0	1	2	0	1	1	0	1	1	1
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	0	5	5	3	4	4	1	2	2	3	4	0
Cap, veh/h	176	1350	145	267	1329	196	313	340	73	261	475	460
Arrive On Green	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sat Flow, veh/h	1690	2904	312	1641	2820	417	1674	1277	275	1641	1827	1436
Grp Volume(v), veh/h	53	402	402	83	591	588	171	0	254	104	218	46
Grp Sat Flow(s),veh/h/ln	1690	1607	1608	1641	1623	1613	1674	0	1552	1641	1827	1436
Q Serve(g_s), s	1.7	25.0	25.0	2.7	36.4	36.5	7.0	0.0	16.4	4.7	11.9	2.9
Cycle Q Clear(g_c), s	1.7	25.0	25.0	2.7	36.4	36.5	7.0	0.0	16.4	4.7	11.9	2.9
Prop In Lane	1.00		0.19	1.00		0.26	1.00		0.18	1.00		1.00
Lane Grp Cap(c), veh/h	176	747	748	267	765	761	313	0	414	261	475	460
V/C Ratio(X)	0.30	0.54	0.54	0.31	0.77	0.77	0.55	0.00	0.61	0.40	0.46	0.10
Avail Cap(c_a), veh/h	229	747	748	308	765	761	313	0	414	271	475	460
HCM Platoon Ratio	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	21.9	39.2	39.3	18.1	44.6	44.7	30.2	0.0	44.9	29.1	43.0	32.7
Incr Delay (d2), s/veh	0.9	2.8	2.8	0.7	7.4	7.5	2.0	0.0	6.7	1.0	3.2	0.4
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.7	0.6	0.6	0.7	1.6	1.6	1.2	0.0	0.8	0.6	6.5	1.2
LnGrp Delay(d),s/veh	22.9	42.0	42.0	18.8	52.0	52.2	32.2	0.0	51.5	30.1	46.1	33.2
LnGrp LOS	C	D	D	B	D	D	C		D	C	D	C
Approach Vol, veh/h		857			1262			425			368	
Approach Delay, s/veh		40.8			49.9			43.7			40.0	
Approach LOS		D			D			D			D	
Timer	1	2	3	4	5	6	7	8				
Assigned Phs	1	2	3	4	5	6	7	8				
Phs Duration (G+Y+Rc), s	7.9	51.1	10.3	30.7	8.5	50.5	11.0	30.0				
Change Period (Y+Rc), s	4.0	6.0	4.0	6.0	4.0	6.0	4.0	6.0				
Max Green Setting (Gmax), s	7.0	42.0	7.0	24.0	7.0	42.0	7.0	24.0				
Max Q Clear Time (g_c+I1), s	3.7	38.5	6.7	18.4	4.7	27.0	9.0	13.9				
Green Ext Time (p_c), s	0.0	3.2	0.0	1.7	0.0	11.8	0.0	2.5				
Intersection Summary												
HCM 2010 Ctrl Delay			45.1									
HCM 2010 LOS			D									

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	82	376	252	228	535	224	273	444	138	150	400	46
Future Volume (veh/h)	82	376	252	228	535	224	273	444	138	150	400	46
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.98	1.00		0.99	0.99		0.98	1.00		0.98
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1707	1727	1000	1757	1863	1683	1707	1719	1000	1723	1744	1000
Adj Flow Rate, veh/h	89	409	274	248	582	243	297	483	150	163	435	50
Adj No. of Lanes	1	2	0	1	1	1	1	2	0	1	2	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	4	2	2	1	2	4	4	3	3	3	2	2
Cap, veh/h	217	769	509	327	823	625	272	710	219	223	868	99
Arrive On Green	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sat Flow, veh/h	1625	1876	1243	1674	1863	1415	1625	2450	756	1641	2992	342
Grp Volume(v), veh/h	89	357	326	248	582	243	297	321	312	163	240	245
Grp Sat Flow(s),veh/h/ln	1625	1640	1478	1674	1863	1415	1625	1633	1572	1641	1657	1677
Q Serve(g_s), s	3.2	21.8	22.0	8.0	31.2	17.2	6.0	19.6	19.9	6.0	14.5	14.6
Cycle Q Clear(g_c), s	3.2	21.8	22.0	8.0	31.2	17.2	6.0	19.6	19.9	6.0	14.5	14.6
Prop In Lane	1.00		0.84	1.00		1.00	1.00		0.48	1.00		0.20
Lane Grp Cap(c), veh/h	217	673	606	327	823	625	272	474	456	223	480	486
V/C Ratio(X)	0.41	0.53	0.54	0.76	0.71	0.39	1.09	0.68	0.68	0.73	0.50	0.50
Avail Cap(c_a), veh/h	252	673	606	327	823	625	272	474	456	223	480	486
HCM Platoon Ratio	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	22.4	40.4	40.5	22.6	43.5	36.5	38.2	45.3	45.4	32.0	42.7	42.8
Incr Delay (d2), s/veh	1.2	3.0	3.4	9.9	5.1	1.8	81.6	7.6	8.1	11.7	3.7	3.7
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.9	10.5	9.6	3.9	1.2	0.3	6.2	9.9	1.0	2.5	7.2	7.3
LnGrp Delay(d),s/veh	23.7	43.4	43.9	32.5	48.6	38.3	119.8	52.9	53.5	43.7	46.4	46.5
LnGrp LOS	C	D	D	C	D	D	F	D	D	D	D	D
Approach Vol, veh/h		772			1073			930			648	
Approach Delay, s/veh		41.3			42.6			74.5			45.8	
Approach LOS		D			D			E			D	
Timer	1	2	3	4	5	6	7	8				
Assigned Phs	1	2	3	4	5	6	7	8				
Phs Duration (G+Y+Rc), s	10.0	33.0	12.0	45.0	10.0	33.0	8.8	48.2				
Change Period (Y+Rc), s	4.0	6.0	4.0	6.0	4.0	6.0	4.0	6.0				
Max Green Setting (Gmax), s	6.0	27.0	8.0	39.0	6.0	27.0	7.0	40.0				
Max Q Clear Time (g_c+I1), s	8.0	21.9	10.0	24.0	8.0	16.6	5.2	33.2				
Green Ext Time (p_c), s	0.0	3.2	0.0	9.3	0.0	5.5	0.0	5.0				
Intersection Summary												
HCM 2010 Ctrl Delay			51.6									
HCM 2010 LOS			D									

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	291	982	19	82	323	8	11	596	364	13	167	116
Future Volume (veh/h)	291	982	19	82	323	8	11	596	364	13	167	116
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.96	1.00		1.00	0.99		0.99	1.00		0.98
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1723	1741	1000	1740	1740	1000	1775	1863	1716	1740	1810	1483
Adj Flow Rate, veh/h	316	1091	21	91	359	9	12	648	404	14	182	126
Adj No. of Lanes	1	2	0	1	2	0	1	1	1	1	1	1
Peak Hour Factor	0.92	0.90	0.92	0.90	0.90	0.90	0.92	0.92	0.90	0.90	0.92	0.92
Percent Heavy Veh, %	3	2	2	2	2	2	0	2	2	2	5	18
Cap, veh/h	587	1142	22	422	1291	32	335	677	522	68	658	432
Arrive On Green	0.15	0.34	0.33	0.21	0.39	0.39	0.35	0.36	0.36	0.36	0.36	0.35
Sat Flow, veh/h	1641	3317	64	1657	3296	83	1010	1863	1437	499	1810	1241
Grp Volume(v), veh/h	316	544	568	91	180	188	12	648	404	14	182	126
Grp Sat Flow(s),veh/h/ln	1641	1654	1727	1657	1653	1726	1010	1863	1437	499	1810	1241
Q Serve(g_s), s	16.0	41.5	41.5	3.2	9.6	9.6	1.1	43.8	32.1	3.1	9.2	9.5
Cycle Q Clear(g_c), s	16.0	41.5	41.5	3.2	9.6	9.6	10.3	43.8	32.1	46.9	9.2	9.5
Prop In Lane	1.00		0.04	1.00		0.05	1.00		1.00	1.00		1.00
Lane Grp Cap(c), veh/h	587	569	594	422	647	676	335	677	522	68	658	432
V/C Ratio(X)	0.54	0.96	0.96	0.22	0.28	0.28	0.04	0.96	0.77	0.21	0.28	0.29
Avail Cap(c_a), veh/h	665	569	594	422	647	676	335	677	522	68	658	432
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	21.6	41.3	41.4	20.5	26.8	26.8	34.1	40.1	36.3	63.2	29.0	30.5
Incr Delay (d2), s/veh	1.6	28.2	27.5	1.2	1.1	1.0	0.2	25.5	10.7	6.8	1.0	1.7
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	7.5	23.3	24.3	1.6	4.5	4.7	0.3	27.3	14.2	0.6	4.8	3.5
LnGrp Delay(d),s/veh	23.3	69.6	68.9	21.7	27.8	27.8	34.3	65.5	47.0	69.9	30.1	32.2
LnGrp LOS	C	E	E	C	C	C	C	E	D	E	C	C
Approach Vol, veh/h		1428			459			1064			322	
Approach Delay, s/veh		59.0			26.6			58.2			32.7	
Approach LOS		E			C			E			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2	3	4		6	7	8
Phs Duration (G+Y+Rc), s		50.9	29.7	48.4		50.9	23.6	54.5
Change Period (Y+Rc), s		6.0	4.0	6.0		6.0	4.0	6.0
Max Green Setting (Gmax), s		42.4	25.7	42.4		44.6	25.7	42.4
Max Q Clear Time (g_c+I1), s		45.8	5.2	43.5		48.9	18.0	11.6
Green Ext Time (p_c), s		0.0	0.3	0.0		0.0	1.6	14.6

Intersection Summary	
HCM 2010 Ctrl Delay	51.6
HCM 2010 LOS	D

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	207	793	133	101	359	114	53	203	101	174	371	35
Future Volume (veh/h)	207	793	133	101	359	114	53	203	101	174	371	35
Number	3	8	18	7	4	14	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.99	1.00		0.99	0.99		0.98	1.00		0.99
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1740	1750	1000	1675	1792	1716	1675	1690	1000	1644	1700	1000
Adj Flow Rate, veh/h	207	793	133	101	359	114	53	203	101	174	371	35
Adj No. of Lanes	1	2	0	1	2	1	1	2	0	2	2	0
Peak Hour Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Percent Heavy Veh, %	2	1	1	6	6	2	6	5	5	8	4	4
Cap, veh/h	443	1072	180	230	1147	488	351	559	266	476	1123	105
Arrive On Green	0.11	0.38	0.36	0.07	0.34	0.34	0.05	0.27	0.25	0.16	0.38	0.36
Sat Flow, veh/h	1657	2847	478	1595	3406	1449	1595	2096	998	3037	2981	280
Grp Volume(v), veh/h	207	463	463	101	359	114	53	153	151	174	200	206
Grp Sat Flow(s),veh/h/ln	1657	1662	1662	1595	1703	1449	1595	1606	1488	1518	1615	1645
Q Serve(g_s), s	9.5	28.9	29.0	5.0	9.4	6.8	2.9	9.3	10.0	6.2	10.6	10.7
Cycle Q Clear(g_c), s	9.5	28.9	29.0	5.0	9.4	6.8	2.9	9.3	10.0	6.2	10.6	10.7
Prop In Lane	1.00		0.29	1.00		1.00	1.00		0.67	1.00		0.17
Lane Grp Cap(c), veh/h	443	626	626	230	1147	488	351	428	397	476	608	620
V/C Ratio(X)	0.47	0.74	0.74	0.44	0.31	0.23	0.15	0.36	0.38	0.37	0.33	0.33
Avail Cap(c_a), veh/h	443	626	626	230	1147	488	351	428	397	476	608	620
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	22.0	32.3	32.6	27.1	29.5	28.7	30.7	35.7	36.5	45.3	26.6	26.8
Incr Delay (d2), s/veh	3.5	7.7	7.7	6.0	0.7	1.1	0.9	2.3	2.7	2.2	1.4	1.4
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	4.7	14.6	14.6	2.5	4.5	2.9	1.4	4.4	4.4	2.7	5.0	5.1
LnGrp Delay(d),s/veh	25.5	40.0	40.2	33.0	30.2	29.8	31.6	38.0	39.2	47.4	28.1	28.2
LnGrp LOS	C	D	D	C	C	C	C	D	D	D	C	C
Approach Vol, veh/h		1133			574			357			580	
Approach Delay, s/veh		37.4			30.6			37.6			33.9	
Approach LOS		D			C			D			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	22.8	36.0	16.8	44.4	9.6	49.2	12.0	49.2
Change Period (Y+Rc), s	6.0	6.0	4.0	6.0	4.0	6.0	4.0	6.0
Max Green Setting (Gmax), s	16.8	30.0	12.8	38.4	5.6	42.0	8.0	43.2
Max Q Clear Time (g_c+I1), s	11.2	12.0	11.5	11.4	4.9	12.7	7.0	31.0
Green Ext Time (p_c), s	0.5	4.7	0.1	12.5	0.0	5.5	0.0	7.6

Intersection Summary	
HCM 2010 Ctrl Delay	35.2
HCM 2010 LOS	D

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	54	221	73	69	204	15	40	242	165	40	406	125
Future Volume (veh/h)	54	221	73	69	204	15	40	242	165	40	406	125
Number	3	8	18	7	4	14	1	6	16	5	2	12
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		0.99	1.00		0.99
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1628	1568	1000	1675	1577	1000	1000	1553	1000	1000	1596	1000
Adj Flow Rate, veh/h	54	221	73	69	204	15	40	242	165	40	406	125
Adj No. of Lanes	1	1	0	1	1	0	0	2	0	0	2	0
Peak Hour Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Percent Heavy Veh, %	9	3	3	6	5	5	6	6	6	3	3	3
Cap, veh/h	407	463	153	348	595	44	132	706	471	115	1013	303
Arrive On Green	0.41	0.41	0.38	0.41	0.41	0.38	0.98	0.98	0.93	0.49	0.49	0.47
Sat Flow, veh/h	1011	1128	373	971	1451	107	162	1441	961	130	2067	619
Grp Volume(v), veh/h	54	0	294	69	0	219	235	0	212	301	0	270
Grp Sat Flow(s),veh/h/ln	1011	0	1501	971	0	1557	1327	0	1237	1477	0	1339
Q Serve(g_s), s	3.1	0.0	11.6	4.5	0.0	7.7	0.6	0.0	1.2	0.0	0.0	10.5
Cycle Q Clear(g_c), s	10.8	0.0	11.6	16.1	0.0	7.7	11.1	0.0	1.2	9.5	0.0	10.5
Prop In Lane	1.00		0.25	1.00		0.07	0.17		0.78	0.13		0.46
Lane Grp Cap(c), veh/h	407	0	615	348	0	639	703	0	606	775	0	656
V/C Ratio(X)	0.13	0.00	0.48	0.20	0.00	0.34	0.33	0.00	0.35	0.39	0.00	0.41
Avail Cap(c_a), veh/h	407	0	615	348	0	639	703	0	606	775	0	656
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00	2.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	19.9	0.0	17.5	23.2	0.0	16.3	0.4	0.0	1.2	12.8	0.0	13.4
Incr Delay (d2), s/veh	0.7	0.0	2.6	1.3	0.0	1.5	1.3	0.0	1.6	1.5	0.0	1.9
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.9	0.0	5.2	1.3	0.0	3.6	0.4	0.0	0.6	4.5	0.0	4.2
LnGrp Delay(d),s/veh	20.6	0.0	20.2	24.5	0.0	17.7	1.7	0.0	2.8	14.3	0.0	15.3
LnGrp LOS	C		C	C		B	A		A	B		B
Approach Vol, veh/h		348			288			447			571	
Approach Delay, s/veh		20.2			19.3			2.2			14.8	
Approach LOS		C			B			A			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		8
Phs Duration (G+Y+Rc), s		43.2		36.8		43.2		36.8
Change Period (Y+Rc), s		6.0		6.0		6.0		6.0
Max Green Setting (Gmax), s		37.2		30.8		37.2		30.8
Max Q Clear Time (g_c+I1), s		12.5		18.1		13.1		13.6
Green Ext Time (p_c), s		8.4		3.7		8.3		4.3

Intersection Summary	
HCM 2010 Ctrl Delay	13.3
HCM 2010 LOS	B

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	538	346	2	63	111	53	1	286	77	150	265	229
Future Volume (veh/h)	538	346	2	63	111	53	1	286	77	150	265	229
Number	5	2	12	1	6	16	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		0.99	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1723	1775	1000	1707	1757	962	1775	1720	1000	1757	1810	1577
Adj Flow Rate, veh/h	585	376	2	68	121	58	1	311	84	163	288	249
Adj No. of Lanes	1	1	1	1	1	1	1	2	0	1	2	1
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	3	0	0	4	1	4	0	3	3	1	5	11
Cap, veh/h	707	900	430	477	694	322	232	497	132	248	1014	595
Arrive On Green	0.15	0.51	0.51	0.04	0.40	0.40	0.19	0.19	0.19	0.06	0.29	0.29
Sat Flow, veh/h	1641	1775	849	1625	1757	816	822	2552	678	1674	3438	1336
Grp Volume(v), veh/h	585	376	2	68	121	58	1	197	198	163	288	249
Grp Sat Flow(s),veh/h/ln	1641	1775	849	1625	1757	816	822	1634	1596	1674	1719	1336
Q Serve(g_s), s	15.0	13.3	0.1	2.5	4.5	4.6	0.1	11.1	11.4	6.0	6.4	12.7
Cycle Q Clear(g_c), s	15.0	13.3	0.1	2.5	4.5	4.6	0.1	11.1	11.4	6.0	6.4	12.7
Prop In Lane	1.00		1.00	1.00		1.00	1.00		0.42	1.00		1.00
Lane Grp Cap(c), veh/h	707	900	430	477	694	322	232	318	311	248	1014	595
V/C Ratio(X)	0.83	0.42	0.00	0.14	0.17	0.18	0.00	0.62	0.64	0.66	0.28	0.42
Avail Cap(c_a), veh/h	707	900	430	513	694	322	302	457	447	248	1306	709
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	18.1	15.4	12.2	16.8	19.6	19.7	32.5	36.9	37.0	33.1	27.1	18.9
Incr Delay (d2), s/veh	8.1	1.4	0.0	0.1	0.5	1.2	0.0	2.0	2.2	6.3	0.2	0.5
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	10.8	6.8	0.0	1.1	2.3	1.1	0.0	5.2	5.2	3.9	3.1	4.7
LnGrp Delay(d),s/veh	26.2	16.8	12.2	16.9	20.2	20.9	32.5	38.8	39.2	39.4	27.3	19.4
LnGrp LOS	C	B	B	B	C	C	C	D	D	D	C	B
Approach Vol, veh/h		963			247			396			700	
Approach Delay, s/veh		22.5			19.5			39.0			27.3	
Approach LOS		C			B			D			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6		8
Phs Duration (G+Y+Rc), s	7.8	56.7	10.0	25.5	19.0	45.5		35.5
Change Period (Y+Rc), s	4.0	6.0	4.0	6.0	4.0	6.0		6.0
Max Green Setting (Gmax), s	6.0	40.0	6.0	28.0	15.0	31.0		38.0
Max Q Clear Time (g_c+I1), s	4.5	15.3	8.0	13.4	17.0	6.6		14.7
Green Ext Time (p_c), s	0.0	4.1	0.0	5.6	0.0	4.1		6.9

Intersection Summary	
HCM 2010 Ctrl Delay	26.5
HCM 2010 LOS	C

Intersection	
Int Delay, s/veh	4.9

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	6	4	39	117	10	150	14	339	42	3	490	42
Future Vol, veh/h	6	4	39	117	10	150	14	339	42	3	490	42
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Stop	Stop	Stop	Stop	Stop	Stop	Free	Free	Free	Free	Free	Free
RT Channelized	-	-	None	-	-	None	-	-	None	-	-	None
Storage Length	-	-	-	-	-	0	-	-	-	-	-	-
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	90	90	90	90	90	90	90	90	90	90	90	90
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	7	4	43	130	11	167	16	377	47	3	544	47

Major/Minor	Minor2			Minor1			Major1			Major2		
Conflicting Flow All	800	1030	296	713	1030	212	591	0	0	424	0	0
Stage 1	574	574	-	433	433	-	-	-	-	-	-	-
Stage 2	226	456	-	280	597	-	-	-	-	-	-	-
Critical Hdwy	7.54	6.54	6.94	7.54	6.54	6.94	4.14	-	-	4.14	-	-
Critical Hdwy Stg 1	6.54	5.54	-	6.54	5.54	-	-	-	-	-	-	-
Critical Hdwy Stg 2	6.54	5.54	-	6.54	5.54	-	-	-	-	-	-	-
Follow-up Hdwy	3.52	4.02	3.32	3.52	4.02	3.32	2.22	-	-	2.22	-	-
Pot Cap-1 Maneuver	276	232	700	319	232	793	981	-	-	1132	-	-
Stage 1	471	501	-	571	580	-	-	-	-	-	-	-
Stage 2	756	567	-	703	490	-	-	-	-	-	-	-
Platoon blocked, %								-	-		-	-
Mov Cap-1 Maneuver	206	226	700	289	226	793	981	-	-	1132	-	-
Mov Cap-2 Maneuver	206	226	-	289	226	-	-	-	-	-	-	-
Stage 1	461	499	-	559	568	-	-	-	-	-	-	-
Stage 2	573	555	-	651	488	-	-	-	-	-	-	-

Approach	EB	WB	NB	SB
HCM Control Delay, s	13.5	19.4	0.4	0
HCM LOS	B	C		

Minor Lane/Major Mvmt	NBL	NBT	NBR	EBLn1	WBLn1	WBLn2	SBL	SBT	SBR
Capacity (veh/h)	981	-	-	478	283	793	1132	-	-
HCM Lane V/C Ratio	0.016	-	-	0.114	0.499	0.21	0.003	-	-
HCM Control Delay (s)	8.7	0.1	-	13.5	29.7	10.7	8.2	0	-
HCM Lane LOS	A	A	-	B	D	B	A	A	-
HCM 95th %tile Q(veh)	0	-	-	0.4	2.6	0.8	0	-	-

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	78	0	17	0	0	0	29	491	0	0	494	126
Future Volume (veh/h)	78	0	17	0	0	0	29	491	0	0	494	126
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1740	1618	1000	1000	1520	1000	1000	1618	1000	1000	1618	1716
Adj Flow Rate, veh/h	87	0	19	0	0	0	32	546	0	0	549	140
Adj No. of Lanes	1	1	0	0	1	0	0	2	0	0	2	1
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	394	0	215	0	238	0	137	1938	0	0	2132	1012
Arrive On Green	0.16	0.00	0.16	0.00	0.00	0.00	0.69	0.69	0.00	0.00	0.69	0.69
Sat Flow, veh/h	1657	0	1375	0	1520	0	90	2867	0	0	3154	1458
Grp Volume(v), veh/h	87	0	19	0	0	0	301	277	0	0	549	140
Grp Sat Flow(s),veh/h/ln	1657	0	1375	0	1520	0	1485	1398	0	0	1537	1458
Q Serve(g_s), s	2.5	0.0	0.6	0.0	0.0	0.0	0.0	4.0	0.0	0.0	3.6	1.7
Cycle Q Clear(g_c), s	2.5	0.0	0.6	0.0	0.0	0.0	3.7	4.0	0.0	0.0	3.6	1.7
Prop In Lane	1.00		1.00	0.00		0.00	0.11		0.00	0.00		1.00
Lane Grp Cap(c), veh/h	394	0	215	0	238	0	1105	970	0	0	2132	1012
V/C Ratio(X)	0.22	0.00	0.09	0.00	0.00	0.00	0.27	0.29	0.00	0.00	0.26	0.14
Avail Cap(c_a), veh/h	819	0	567	0	627	0	1105	970	0	0	2132	1012
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00	1.00	1.00
Uniform Delay (d), s/veh	20.0	0.0	19.2	0.0	0.0	0.0	3.1	3.1	0.0	0.0	3.0	2.8
Incr Delay (d2), s/veh	0.3	0.0	0.2	0.0	0.0	0.0	0.6	0.7	0.0	0.0	0.3	0.3
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	1.2	0.0	0.2	0.0	0.0	0.0	1.8	1.7	0.0	0.0	1.5	0.8
LnGrp Delay(d),s/veh	20.3	0.0	19.4	0.0	0.0	0.0	3.7	3.9	0.0	0.0	3.3	3.1
LnGrp LOS	C		B				A	A			A	A
Approach Vol, veh/h		106			0			578			689	
Approach Delay, s/veh		20.2			0.0			3.8			3.3	
Approach LOS		C						A			A	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		8
Phs Duration (G+Y+Rc), s		41.0		12.3		41.0		12.3
Change Period (Y+Rc), s		6.0		6.0		6.0		6.0
Max Green Setting (Gmax), s		35.0		20.0		35.0		20.0
Max Q Clear Time (g_c+I1), s		6.0		4.5		5.6		0.0
Green Ext Time (p_c), s		11.4		0.3		11.5		0.0

Intersection Summary	
HCM 2010 Ctrl Delay	4.8
HCM 2010 LOS	A

Intersection	
Intersection Delay, s/veh	22.4
Intersection LOS	C

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	107	35	377	53	34	13	88	184	21	9	287	33
Future Vol, veh/h	107	35	377	53	34	13	88	184	21	9	287	33
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	119	39	419	59	38	14	98	204	23	10	319	37
Number of Lanes	0	1	1	0	1	0	1	1	0	0	1	0

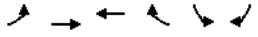
Approach	EB	WB	NB	SB
Opposing Approach	WB	EB	SB	NB
Opposing Lanes	1	2	1	2
Conflicting Approach Left	SB	NB	EB	WB
Conflicting Lanes Left	1	2	2	1
Conflicting Approach Right	NB	SB	WB	EB
Conflicting Lanes Right	2	1	1	2
HCM Control Delay	23.5	14.4	15.8	29
HCM LOS	C	B	C	D

Lane	NBLn1	NBLn2	EBLn1	EBLn2	WBLn1	SBLn1
Vol Left, %	100%	0%	75%	0%	53%	3%
Vol Thru, %	0%	90%	25%	0%	34%	87%
Vol Right, %	0%	10%	0%	100%	13%	10%
Sign Control	Stop	Stop	Stop	Stop	Stop	Stop
Traffic Vol by Lane	88	205	142	377	100	329
LT Vol	88	0	107	0	53	9
Through Vol	0	184	35	0	34	287
RT Vol	0	21	0	377	13	33
Lane Flow Rate	98	228	158	419	111	366
Geometry Grp	7	7	7	7	6	6
Degree of Util (X)	0.22	0.475	0.334	0.758	0.258	0.745
Departure Headway (Hd)	8.088	7.5	7.619	6.516	8.365	7.334
Convergence, Y/N	Yes	Yes	Yes	Yes	Yes	Yes
Cap	443	478	472	553	428	494
Service Time	5.857	5.269	5.378	4.275	6.455	5.395
HCM Lane V/C Ratio	0.221	0.477	0.335	0.758	0.259	0.741
HCM Control Delay	13.1	16.9	14.2	27	14.4	29
HCM Lane LOS	B	C	B	D	B	D
HCM 95th-tile Q	0.8	2.5	1.5	6.7	1	6.2

Movement	EBL	EBR	NBL	NBT	SBT	SBR
Lane Configurations						
Traffic Volume (veh/h)	232	35	26	769	237	115
Future Volume (veh/h)	232	35	26	769	237	115
Number	7	14	5	2	6	16
Initial Q (Qb), veh	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00	1.00	1.00			1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1740	1683	1644	1863	1863	1716
Adj Flow Rate, veh/h	258	38	28	854	263	128
Adj No. of Lanes	1	1	1	2	2	1
Peak Hour Factor	0.90	0.92	0.92	0.90	0.90	0.90
Percent Heavy Veh, %	2	4	8	2	2	2
Cap, veh/h	327	282	684	2584	2584	1065
Arrive On Green	0.20	0.20	0.73	0.73	0.73	0.73
Sat Flow, veh/h	1657	1430	872	3632	3632	1458
Grp Volume(v), veh/h	258	38	28	854	263	128
Grp Sat Flow(s),veh/h/ln	1657	1430	872	1770	1770	1458
Q Serve(g_s), s	16.3	2.4	1.1	9.4	2.4	2.9
Cycle Q Clear(g_c), s	16.3	2.4	3.4	9.4	2.4	2.9
Prop In Lane	1.00	1.00	1.00			1.00
Lane Grp Cap(c), veh/h	327	282	684	2584	2584	1065
V/C Ratio(X)	0.79	0.13	0.04	0.33	0.10	0.12
Avail Cap(c_a), veh/h	768	663	684	2584	2584	1065
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	0.98	0.98
Uniform Delay (d), s/veh	42.0	36.4	4.8	5.3	4.3	4.4
Incr Delay (d2), s/veh	4.3	0.2	0.1	0.3	0.0	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	7.8	1.0	0.3	4.6	1.2	1.2
LnGrp Delay(d),s/veh	46.3	36.6	4.9	5.6	4.3	4.4
LnGrp LOS	D	D	A	A	A	A
Approach Vol, veh/h	296			882	391	
Approach Delay, s/veh	45.0			5.6	4.4	
Approach LOS	D			A	A	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		
Phs Duration (G+Y+Rc), s		84.3		25.7		84.3		
Change Period (Y+Rc), s		6.0		6.0		6.0		
Max Green Setting (Gmax), s		49.0		49.0		12.0		
Max Q Clear Time (g_c+I1), s		11.4		18.3		4.9		
Green Ext Time (p_c), s		13.4		1.4		4.8		

Intersection Summary	
HCM 2010 Ctrl Delay	12.7
HCM 2010 LOS	B



Movement	EBL	EBT	WBT	WBR	SBL	SBR		
Lane Configurations								
Traffic Volume (veh/h)	174	685	315	74	256	345		
Future Volume (veh/h)	174	685	315	74	256	345		
Number	5	2	6	16	7	14		
Initial Q (Qb), veh	0	0	0	0	0	0		
Ped-Bike Adj(A_pbT)	1.00			1.00	1.00	1.00		
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00		
Adj Sat Flow, veh/h/ln	1707	1845	1810	1535	1757	1699		
Adj Flow Rate, veh/h	189	745	342	80	278	375		
Adj No. of Lanes	1	2	2	1	1	1		
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92		
Percent Heavy Veh, %	4	3	5	14	1	3		
Cap, veh/h	555	2089	1618	613	527	455		
Arrive On Green	0.08	0.60	0.47	0.47	0.31	0.31		
Sat Flow, veh/h	1625	3597	3529	1303	1674	1444		
Grp Volume(v), veh/h	189	745	342	80	278	375		
Grp Sat Flow(s),veh/h/ln	1625	1752	1719	1303	1674	1444		
Q Serve(g_s), s	5.3	9.8	5.3	3.1	12.3	21.6		
Cycle Q Clear(g_c), s	5.3	9.8	5.3	3.1	12.3	21.6		
Prop In Lane	1.00			1.00	1.00	1.00		
Lane Grp Cap(c), veh/h	555	2089	1618	613	527	455		
V/C Ratio(X)	0.34	0.36	0.21	0.13	0.53	0.82		
Avail Cap(c_a), veh/h	568	2089	1618	613	707	610		
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00		
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00		
Uniform Delay (d), s/veh	10.6	9.3	14.0	13.4	25.3	28.5		
Incr Delay (d2), s/veh	0.4	0.5	0.3	0.4	0.8	6.8		
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0		
%ile BackOfQ(50%),veh/ln	2.4	4.8	2.5	1.2	5.8	16.6		
LnGrp Delay(d),s/veh	11.0	9.8	14.3	13.9	26.1	35.3		
LnGrp LOS	B	A	B	B	C	D		
Approach Vol, veh/h		934	422		653			
Approach Delay, s/veh		10.0	14.2		31.4			
Approach LOS		B	B		C			
Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4	5	6		
Phs Duration (G+Y+Rc), s		57.7		32.3	11.3	46.4		
Change Period (Y+Rc), s		6.0		6.0	4.0	6.0		
Max Green Setting (Gmax), s		42.0		36.0	8.0	30.0		
Max Q Clear Time (g_c+I1), s		11.8		23.6	7.3	7.3		
Green Ext Time (p_c), s		11.0		2.7	0.1	9.7		
Intersection Summary								
HCM 2010 Ctrl Delay			17.9					
HCM 2010 LOS			B					

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	100	401	6	94	155	67	1	58	10	111	262	49
Future Volume (veh/h)	100	401	6	94	155	67	1	58	10	111	262	49
Number	1	6	16	5	2	12	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.99	1.00		0.99	0.99		0.96	0.99		0.99
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1740	1634	1000	1775	1863	1636	1775	1474	1000	1757	1590	1000
Adj Flow Rate, veh/h	109	436	7	102	168	73	1	63	11	121	285	53
Adj No. of Lanes	1	1	0	1	1	1	1	1	0	1	1	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	1	1	0	2	7	0	14	14	1	3	3
Cap, veh/h	603	796	13	264	967	717	150	189	33	350	371	69
Arrive On Green	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sat Flow, veh/h	1657	1603	26	1690	1863	1382	983	1215	212	1674	1302	242
Grp Volume(v), veh/h	109	0	443	102	168	73	1	0	74	121	0	338
Grp Sat Flow(s),veh/h/ln	1657	0	1629	1690	1863	1382	983	0	1427	1674	0	1544
Q Serve(g_s), s	2.8	0.0	23.1	1.5	7.6	4.5	0.1	0.0	4.4	4.9	0.0	18.6
Cycle Q Clear(g_c), s	2.8	0.0	23.1	1.5	7.6	4.5	7.6	0.0	4.4	4.9	0.0	18.6
Prop In Lane	1.00		0.02	1.00		1.00	1.00		0.15	1.00		0.16
Lane Grp Cap(c), veh/h	603	0	808	264	967	717	150	0	222	350	0	440
V/C Ratio(X)	0.18	0.00	0.55	0.39	0.17	0.10	0.01	0.00	0.33	0.35	0.00	0.77
Avail Cap(c_a), veh/h	611	0	808	353	967	717	206	0	303	350	0	528
HCM Platoon Ratio	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upstream Filter(I)	1.00	0.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	11.0	0.0	32.9	24.0	24.2	22.6	43.4	0.0	38.0	27.5	0.0	39.6
Incr Delay (d2), s/veh	0.1	0.0	2.7	0.9	0.4	0.3	0.0	0.0	0.9	0.6	0.0	5.6
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.2	0.0	0.6	1.5	4.1	0.1	0.0	0.0	0.1	0.3	0.0	0.7
LnGrp Delay(d),s/veh	11.1	0.0	35.5	24.9	24.6	22.9	43.4	0.0	38.9	28.1	0.0	45.2
LnGrp LOS	B		D	C	C	C	D		D	C		D
Approach Vol, veh/h		552			343			75			459	
Approach Delay, s/veh		30.7			24.3			38.9			40.7	
Approach LOS		C			C			D			D	
Timer	1	2	3	4	5	6	7	8				
Assigned Phs	1	2	3	4	5	6		8				
Phs Duration (G+Y+Rc), s	8.6	48.0	11.0	17.2	10.5	46.1		28.2				
Change Period (Y+Rc), s	4.0	6.0	6.0	6.0	6.0	6.0		6.0				
Max Green Setting (Gmax), s	5.0	42.0	5.0	16.0	9.0	36.0		27.0				
Max Q Clear Time (g_c+I1), s	4.8	9.6	6.9	9.6	3.5	25.1		20.6				
Green Ext Time (p_c), s	0.0	5.6	0.0	1.5	0.1	3.6		1.5				
Intersection Summary												
HCM 2010 Ctrl Delay			32.8									
HCM 2010 LOS			C									

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	71	614	77	35	518	312	199	726	57	157	220	64
Future Volume (veh/h)	71	614	77	35	518	312	199	726	57	157	220	64
Number	1	6	16	5	2	12	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	0.99		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1740	1845	1683	1740	1863	1716	1757	1863	1716	1740	1740	1000
Adj Flow Rate, veh/h	79	667	0	38	563	0	216	807	0	174	244	71
Adj No. of Lanes	1	2	1	1	2	1	1	2	1	1	2	0
Peak Hour Factor	0.90	0.92	0.92	0.92	0.92	0.90	0.92	0.90	0.92	0.90	0.90	0.90
Percent Heavy Veh, %	2	3	4	2	2	2	1	2	2	2	2	2
Cap, veh/h	308	1212	495	249	1452	623	510	1382	569	354	956	272
Arrive On Green	0.36	0.35	0.00	0.03	0.41	0.00	0.09	0.39	0.00	0.10	0.38	0.38
Sat Flow, veh/h	781	3505	1430	1657	3539	1458	1674	3539	1458	1657	2542	724
Grp Volume(v), veh/h	79	667	0	38	563	0	216	807	0	174	157	158
Grp Sat Flow(s),veh/h/ln	781	1752	1430	1657	1770	1458	1674	1770	1458	1657	1653	1613
Q Serve(g_s), s	9.0	18.0	0.0	1.7	13.1	0.0	9.5	21.1	0.0	7.2	7.6	7.9
Cycle Q Clear(g_c), s	14.5	18.0	0.0	1.7	13.1	0.0	9.5	21.1	0.0	7.2	7.6	7.9
Prop In Lane	1.00		1.00	1.00		1.00	1.00		1.00	1.00		0.45
Lane Grp Cap(c), veh/h	308	1212	495	249	1452	623	510	1382	569	354	622	606
V/C Ratio(X)	0.26	0.55	0.00	0.15	0.39	0.00	0.42	0.58	0.00	0.49	0.25	0.26
Avail Cap(c_a), veh/h	308	1212	495	298	1452	623	510	1382	569	378	622	606
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	0.00	1.00	1.00	0.00	0.91	0.91	0.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	30.5	30.9	0.0	23.9	24.2	0.0	20.4	28.2	0.0	20.4	25.2	25.3
Incr Delay (d2), s/veh	2.0	1.8	0.0	0.3	0.8	0.0	0.5	0.6	0.0	1.1	1.0	1.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	2.1	9.0	0.0	0.8	6.5	0.0	4.4	10.4	0.0	3.3	3.7	3.7
LnGrp Delay(d),s/veh	32.5	32.7	0.0	24.1	25.0	0.0	20.9	28.7	0.0	21.4	26.1	26.3
LnGrp LOS	C	C		C	C		C	C		C	C	C
Approach Vol, veh/h		746			601			1023			489	
Approach Delay, s/veh		32.7			24.9			27.1			24.5	
Approach LOS		C			C			C			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s		54.0	13.3	49.7	7.5	46.5	15.0	48.0
Change Period (Y+Rc), s		6.0	4.0	6.0	4.0	6.0	4.0	6.0
Max Green Setting (Gmax), s		37.0	11.0	12.0	7.0	37.0	11.0	42.0
Max Q Clear Time (g_c+I1), s		15.1	9.2	23.1	3.7	20.0	11.5	9.9
Green Ext Time (p_c), s		11.2	0.1	0.0	0.0	9.6	0.0	11.1

Intersection Summary	
HCM 2010 Ctrl Delay	27.7
HCM 2010 LOS	C

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	42	42	1	52	41	62	6	874	171	43	689	75
Future Volume (veh/h)	42	42	1	52	41	62	6	874	171	43	689	75
Number	3	8	18	7	4	14	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	0.99		0.99	0.99		0.99	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1690	1650	1000	1740	1584	1000	1000	1607	1000	1000	1709	1733
Adj Flow Rate, veh/h	46	46	1	57	45	67	7	950	186	47	749	0
Adj No. of Lanes	1	1	0	1	1	0	0	2	0	0	2	1
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	5	0	0	2	3	3	3	3	3	4	4	1
Cap, veh/h	199	300	7	269	107	159	37	1842	358	129	1942	1091
Arrive On Green	0.19	0.19	0.17	0.19	0.19	0.17	0.72	0.74	0.72	0.72	0.74	0.00
Sat Flow, veh/h	1149	1608	35	1252	571	850	5	2487	484	124	2622	1473
Grp Volume(v), veh/h	46	0	47	57	0	112	614	0	529	370	426	0
Grp Sat Flow(s),veh/h/ln	1149	0	1643	1252	0	1421	1599	0	1376	1269	1477	1473
Q Serve(g_s), s	4.1	0.0	2.6	4.4	0.0	7.7	0.0	0.0	18.2	1.9	11.6	0.0
Cycle Q Clear(g_c), s	11.8	0.0	2.6	7.0	0.0	7.7	17.9	0.0	18.2	20.1	11.6	0.0
Prop In Lane	1.00		0.02	1.00		0.60	0.01		0.35	0.13		1.00
Lane Grp Cap(c), veh/h	199	0	307	269	0	265	1188	0	1019	954	1094	1091
V/C Ratio(X)	0.23	0.00	0.15	0.21	0.00	0.42	0.52	0.00	0.52	0.39	0.39	0.00
Avail Cap(c_a), veh/h	345	0	515	428	0	446	1188	0	1019	954	1094	1091
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00
Uniform Delay (d), s/veh	44.7	0.0	37.5	40.4	0.0	40.0	6.0	0.0	6.2	4.9	5.2	0.0
Incr Delay (d2), s/veh	0.6	0.0	0.2	0.4	0.0	1.1	1.6	0.0	1.9	1.2	1.0	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	1.3	0.0	1.2	1.5	0.0	3.1	9.0	0.0	7.4	4.3	4.9	0.0
LnGrp Delay(d),s/veh	45.3	0.0	37.7	40.8	0.0	41.1	7.6	0.0	8.1	6.1	6.2	0.0
LnGrp LOS	D		D	D		D	A		A	A	A	
Approach Vol, veh/h		93			169			1143			796	
Approach Delay, s/veh		41.5			41.0			7.9			6.2	
Approach LOS		D			D			A			A	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		8
Phs Duration (G+Y+Rc), s		85.5		24.5		85.5		24.5
Change Period (Y+Rc), s		6.0		6.0		6.0		6.0
Max Green Setting (Gmax), s		65.5		32.5		65.5		32.5
Max Q Clear Time (g_c+I1), s		20.2		9.7		22.1		13.8
Green Ext Time (p_c), s		26.0		1.6		25.4		1.5

Intersection Summary	
HCM 2010 Ctrl Delay	11.2
HCM 2010 LOS	B

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	240	699	142	71	261	81	108	716	117	183	474	94
Future Volume (veh/h)	240	699	142	71	261	81	108	716	117	183	474	94
Number	1	6	16	5	2	12	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.99	1.00		0.99	1.00		0.99	1.00		0.99
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1740	1701	1000	1775	1635	1000	1675	1690	1000	1740	1696	1000
Adj Flow Rate, veh/h	261	760	154	77	284	88	117	778	127	199	515	102
Adj No. of Lanes	1	2	0	1	2	0	1	2	0	1	2	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	4	4	0	10	10	6	5	5	2	5	5
Cap, veh/h	439	981	199	213	695	211	310	929	152	298	1035	204
Arrive On Green	0.13	0.37	0.35	0.06	0.30	0.28	0.11	0.67	0.64	0.11	0.39	0.37
Sat Flow, veh/h	1657	2676	542	1690	2344	712	1595	2759	450	1657	2678	528
Grp Volume(v), veh/h	261	459	455	77	186	186	117	453	452	199	309	308
Grp Sat Flow(s),veh/h/ln	1657	1616	1602	1690	1553	1503	1595	1606	1603	1657	1611	1595
Q Serve(g_s), s	12.9	30.1	30.2	3.8	11.5	12.0	6.0	25.4	25.6	9.1	17.5	17.7
Cycle Q Clear(g_c), s	12.9	30.1	30.2	3.8	11.5	12.0	6.0	25.4	25.6	9.1	17.5	17.7
Prop In Lane	1.00		0.34	1.00		0.47	1.00		0.28	1.00		0.33
Lane Grp Cap(c), veh/h	439	593	587	213	461	446	310	541	540	298	623	617
V/C Ratio(X)	0.59	0.77	0.77	0.36	0.40	0.42	0.38	0.84	0.84	0.67	0.50	0.50
Avail Cap(c_a), veh/h	439	593	587	213	461	446	310	541	540	298	623	617
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00	2.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	24.8	33.6	33.9	30.0	33.7	34.3	24.3	17.1	17.7	26.0	27.9	28.3
Incr Delay (d2), s/veh	5.8	9.5	9.6	4.7	2.6	2.9	3.5	14.4	14.4	11.3	2.8	2.9
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	6.6	15.0	14.9	2.0	5.2	5.3	2.9	13.0	13.0	5.1	8.2	8.3
LnGrp Delay(d),s/veh	30.7	43.2	43.6	34.7	36.3	37.1	27.8	31.5	32.1	37.3	30.7	31.1
LnGrp LOS	C	D	D	C	D	D	C	C	C	D	C	C
Approach Vol, veh/h		1175			449			1022			816	
Approach Delay, s/veh		40.5			36.4			31.3			32.5	
Approach LOS		D			D			C			C	
Timer	1	2	3	4	5	6	7	8				
Assigned Phs	1	2	3	4	5	6	7	8				
Phs Duration (G+Y+Rc), s	9.2	39.6	16.8	44.4	10.8	48.0	10.8	50.4				
Change Period (Y+Rc), s	4.0	6.0	4.0	6.0	4.0	6.0	4.0	6.0				
Max Green Setting (Gmax), s	5.2	33.6	12.8	38.4	6.8	42.0	6.8	44.4				
Max Q Clear Time (g_c+I1), s	14.9	14.0	11.1	27.6	5.8	32.2	8.0	19.7				
Green Ext Time (p_c), s	0.0	9.6	0.1	7.3	0.0	6.0	0.0	12.9				
Intersection Summary												
HCM 2010 Ctrl Delay			35.4									
HCM 2010 LOS			D									

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	154	549	252	98	121	9	162	671	347	20	720	65
Future Volume (veh/h)	154	549	252	98	121	9	162	671	347	20	720	65
Number	3	8	18	7	4	14	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	0.99		0.98	1.00		0.99	1.00		0.99	1.00		0.97
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1707	1900	1683	1740	1717	1000	1675	1810	1750	1740	1726	1000
Adj Flow Rate, veh/h	167	597	274	107	132	10	176	729	377	22	783	71
Adj No. of Lanes	1	2	1	1	2	0	1	2	1	1	2	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	4	0	4	2	3	3	6	5	0	2	2	2
Cap, veh/h	479	1215	473	265	1035	78	340	1484	634	253	1181	107
Arrive On Green	0.06	0.34	0.34	0.06	0.34	0.32	0.08	0.43	0.43	0.08	0.78	0.74
Sat Flow, veh/h	1625	3610	1405	1657	3075	231	1595	3438	1468	1657	3034	275
Grp Volume(v), veh/h	167	597	274	107	69	73	176	729	377	22	423	431
Grp Sat Flow(s),veh/h/ln	1625	1805	1405	1657	1632	1674	1595	1719	1468	1657	1640	1669
Q Serve(g_s), s	6.8	15.8	19.3	5.2	3.5	3.6	7.8	18.4	23.6	0.9	14.2	14.4
Cycle Q Clear(g_c), s	6.8	15.8	19.3	5.2	3.5	3.6	7.8	18.4	23.6	0.9	14.2	14.4
Prop In Lane	1.00		1.00	1.00		0.14	1.00		1.00	1.00		0.16
Lane Grp Cap(c), veh/h	479	1215	473	265	549	563	340	1484	634	253	638	649
V/C Ratio(X)	0.35	0.49	0.58	0.40	0.13	0.13	0.52	0.49	0.59	0.09	0.66	0.66
Avail Cap(c_a), veh/h	479	1215	473	265	549	563	407	1484	634	278	638	649
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00	2.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	26.7	31.6	32.8	26.2	27.6	27.7	20.3	24.6	26.1	20.7	9.7	10.0
Incr Delay (d2), s/veh	0.4	1.4	5.1	1.0	0.5	0.5	1.2	1.2	4.1	0.1	5.4	5.3
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	1.1	8.1	8.2	2.4	1.7	1.8	3.5	8.9	10.3	0.4	7.0	7.2
LnGrp Delay(d),s/veh	27.1	33.1	37.9	27.2	28.0	28.2	21.6	25.8	30.2	20.8	15.1	15.3
LnGrp LOS	C	C	D	C	C	C	C	C	C	C	B	B
Approach Vol, veh/h		1038			249			1282			876	
Approach Delay, s/veh		33.4			27.7			26.5			15.3	
Approach LOS		C			C			C			B	
Timer	1	2	3	4	5	6	7	8				
Assigned Phs	1	2	3	4	5	6	7	8				
Phs Duration (G+Y+Rc), s	9.0	55.8	10.8	44.4	14.1	50.7	10.8	44.4				
Change Period (Y+Rc), s	4.0	6.0	4.0	6.0	4.0	6.0	4.0	6.0				
Max Green Setting (Gmax), s	6.8	48.0	6.8	38.4	15.2	38.4	6.8	38.4				
Max Q Clear Time (g_c+I1), s	12.9	25.6	8.8	5.6	9.8	16.4	7.2	21.3				
Green Ext Time (p_c), s	0.0	15.0	0.0	8.7	0.3	14.8	0.0	6.8				
Intersection Summary												
HCM 2010 Ctrl Delay			25.8									
HCM 2010 LOS			C									

Intersection	
Intersection Delay, s/veh	54.6
Intersection LOS	F

Approach	EB	WB	NB	SB
Entry Lanes	2	2	2	2
Conflicting Circle Lanes	2	2	2	2
Adj Approach Flow, veh/h	876	418	947	1038
Demand Flow Rate, veh/h	897	431	966	1053
Vehicles Circulating, veh/h	1121	978	894	500
Vehicles Exiting, veh/h	368	728	1124	909
Follow-Up Headway, s	3.186	3.186	3.186	3.186
Ped Vol Crossing Leg, #/h	0	1	0	12
Ped Cap Adj	1.000	1.000	1.000	0.992
Approach Delay, s/veh	127.1	12.8	49.3	15.0
Approach LOS	F	B	E	C

Lane	Left	Right	Left	Right	Left	Right	Bypass	Left	Right	Bypass
Designated Moves	LT	R	LT	TR	L	TR	R	LT	TR	R
Assumed Moves	LT	R	LT	TR	L	TR	R	LT	TR	R
RT Channelized							Yield			Yield
Lane Util	0.705	0.295	0.471	0.529	0.235	0.765		0.470	0.530	
Critical Headway, s	4.293	4.113	4.293	4.113	4.293	4.113		4.293	4.113	
Entry Flow, veh/h	632	265	203	228	191	621	154	465	524	64
Cap Entry Lane, veh/h	487	516	543	570	578	604	546	777	796	873
Entry HV Adj Factor	0.975	0.981	0.968	0.972	0.979	0.980	0.980	0.985	0.986	0.990
Flow Entry, veh/h	616	260	196	222	187	609	151	458	517	63
Cap Entry, veh/h	475	506	525	554	566	592	535	759	779	858
V/C Ratio	1.297	0.514	0.374	0.400	0.330	1.028	0.282	0.603	0.663	0.073
Control Delay, s/veh	173.5	17.0	12.8	12.8	11.1	70.7	10.8	14.7	16.5	4.9
LOS	F	C	B	B	B	F	B	B	C	A
95th %tile Queue, veh	26	3	2	2	1	16	1	4	5	0

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	117	1094	197	93	273	24	61	354	319	121	418	24
Future Volume (veh/h)	117	1094	197	93	273	24	61	354	319	121	418	24
Number	1	6	16	5	2	12	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	0.99		0.99	1.00		0.99	0.99		0.98	1.00		0.98
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1740	1863	1733	1690	1637	1000	1659	1739	1000	1740	1881	1750
Adj Flow Rate, veh/h	127	1189	214	101	297	26	66	385	347	132	454	26
Adj No. of Lanes	1	2	1	1	2	0	1	2	0	1	2	1
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	1	5	7	7	7	3	3	2	1	0
Cap, veh/h	554	1755	720	299	1409	122	265	441	385	166	953	388
Arrive On Green	0.11	0.99	0.99	0.05	0.49	0.47	0.06	0.27	0.25	0.06	0.27	0.27
Sat Flow, veh/h	1657	3539	1452	1610	2892	251	1580	1652	1445	1657	3574	1456
Grp Volume(v), veh/h	127	1189	214	101	159	164	66	385	347	132	454	26
Grp Sat Flow(s),veh/h/ln	1657	1770	1452	1610	1555	1588	1580	1652	1445	1657	1787	1456
Q Serve(g_s), s	4.8	1.0	0.2	3.9	7.0	7.1	3.6	26.7	27.9	6.8	12.8	1.6
Cycle Q Clear(g_c), s	4.8	1.0	0.2	3.9	7.0	7.1	3.6	26.7	27.9	6.8	12.8	1.6
Prop In Lane	1.00		1.00	1.00		0.16	1.00		1.00	1.00		1.00
Lane Grp Cap(c), veh/h	554	1755	720	299	758	774	265	441	385	166	953	388
V/C Ratio(X)	0.23	0.68	0.30	0.34	0.21	0.21	0.25	0.87	0.90	0.80	0.48	0.07
Avail Cap(c_a), veh/h	555	1755	720	314	758	774	265	441	385	166	953	388
HCM Platoon Ratio	2.00	2.00	2.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	13.9	0.3	0.2	14.9	17.6	17.7	30.8	42.1	43.5	36.1	37.0	32.9
Incr Delay (d2), s/veh	0.2	2.1	1.1	0.7	0.6	0.6	2.2	20.7	26.6	31.6	1.7	0.3
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	2.2	0.7	0.3	1.8	3.1	3.3	1.7	14.7	14.0	2.7	6.5	0.7
LnGrp Delay(d),s/veh	14.2	2.4	1.3	15.5	18.2	18.3	33.1	62.8	70.0	67.8	38.7	33.2
LnGrp LOS	B	A	A	B	B	B	C	E	E	E	D	C
Approach Vol, veh/h		1530			424			798			612	
Approach Delay, s/veh		3.2			17.6			63.5			44.7	
Approach LOS		A			B			E			D	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	10.7	62.5	10.8	36.0	9.7	63.5	10.8	36.0
Change Period (Y+Rc), s	4.0	6.0	4.0	6.0	4.0	6.0	4.0	6.0
Max Green Setting (Gmax), s	6.8	56.4	6.8	30.0	6.8	56.4	6.8	30.0
Max Q Clear Time (g_c+I1), s	6.8	9.1	8.8	29.9	5.9	3.0	5.6	14.8
Green Ext Time (p_c), s	0.0	21.1	0.0	0.1	0.0	22.1	0.0	8.1

Intersection Summary	
HCM 2010 Ctrl Delay	26.9
HCM 2010 LOS	C

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	203	740	97	101	197	72	122	437	490	242	315	80
Future Volume (veh/h)	203	740	97	101	197	72	122	437	490	242	315	80
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	0.99		0.99	1.00		0.98	0.99		1.00	1.00		0.98
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1757	1863	1651	1675	1671	1000	1690	1863	1699	1740	1845	1651
Adj Flow Rate, veh/h	203	740	97	101	197	72	122	437	0	242	315	80
Adj No. of Lanes	1	2	1	1	2	0	1	2	1	1	2	1
Peak Hour Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Percent Heavy Veh, %	1	2	6	6	7	7	5	2	3	2	3	6
Cap, veh/h	430	1220	479	244	725	256	451	1250	510	459	1391	548
Arrive On Green	0.09	0.34	0.34	0.02	0.10	0.10	0.07	0.35	0.00	0.11	0.40	0.40
Sat Flow, veh/h	1674	3539	1390	1595	2291	808	1610	3539	1444	1657	3505	1380
Grp Volume(v), veh/h	203	740	97	101	134	135	122	437	0	242	315	80
Grp Sat Flow(s),veh/h/ln	1674	1770	1390	1595	1588	1511	1610	1770	1444	1657	1752	1380
Q Serve(g_s), s	10.0	20.8	5.9	5.2	9.4	9.9	5.9	10.9	0.0	11.0	7.1	4.5
Cycle Q Clear(g_c), s	10.0	20.8	5.9	5.2	9.4	9.9	5.9	10.9	0.0	11.0	7.1	4.5
Prop In Lane	1.00		1.00	1.00		0.53	1.00		1.00	1.00		1.00
Lane Grp Cap(c), veh/h	430	1220	479	244	503	479	451	1250	510	459	1391	548
V/C Ratio(X)	0.47	0.61	0.20	0.41	0.27	0.28	0.27	0.35	0.00	0.53	0.23	0.15
Avail Cap(c_a), veh/h	430	1220	479	289	503	479	548	1250	510	486	1391	548
HCM Platoon Ratio	1.00	1.00	1.00	0.33	0.33	0.33	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	25.4	32.6	27.7	29.1	40.9	41.3	23.2	28.6	0.0	21.2	24.0	23.2
Incr Delay (d2), s/veh	0.8	2.2	1.0	1.1	1.3	1.5	0.3	0.8	0.0	0.9	0.4	0.6
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	4.7	10.6	2.4	2.3	4.3	4.3	2.6	5.5	0.0	5.1	3.5	1.8
LnGrp Delay(d),s/veh	26.2	34.8	28.6	30.2	42.2	42.7	23.5	29.4	0.0	22.1	24.3	23.7
LnGrp LOS	C	C	C	C	D	D	C	C		C	C	C
Approach Vol, veh/h		1040			370			559			637	
Approach Delay, s/veh		32.6			39.1			28.1			23.4	
Approach LOS		C			D			C			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	17.2	46.4	11.0	45.4	12.0	51.6	14.4	42.0
Change Period (Y+Rc), s	4.0	6.0	4.0	6.0	4.0	6.0	4.0	6.0
Max Green Setting (Gmax), s	15.2	38.4	10.4	36.0	15.2	38.4	10.4	36.0
Max Q Clear Time (g_c+I1), s	13.0	12.9	7.2	22.8	7.9	9.1	12.0	11.9
Green Ext Time (p_c), s	0.2	6.7	0.1	6.7	0.2	6.9	0.0	9.4

Intersection Summary	
HCM 2010 Ctrl Delay	30.3
HCM 2010 LOS	C

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	241	183	213	35	71	85	71	1054	42	69	508	73
Future Volume (veh/h)	241	183	213	35	71	85	71	1054	42	69	508	73
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	0.99		0.99	0.99		0.99	1.00		0.99	1.00		0.99
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1740	1845	1733	1723	1562	1000	1740	1721	1000	1740	1715	1000
Adj Flow Rate, veh/h	268	203	237	39	79	94	79	1171	47	77	564	81
Adj No. of Lanes	1	1	1	1	1	0	1	2	0	1	2	0
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	2	3	1	3	10	10	2	3	3	2	3	3
Cap, veh/h	394	680	535	333	239	284	371	1442	58	206	1285	184
Arrive On Green	0.37	0.37	0.37	0.37	0.37	0.35	0.05	0.45	0.43	0.05	0.45	0.43
Sat Flow, veh/h	1121	1845	1451	868	647	770	1657	3202	128	1657	2857	409
Grp Volume(v), veh/h	268	203	237	39	0	173	79	597	621	77	321	324
Grp Sat Flow(s),veh/h/ln	1121	1845	1451	868	0	1417	1657	1635	1696	1657	1629	1636
Q Serve(g_s), s	20.4	7.0	11.1	3.0	0.0	8.0	2.4	28.5	28.6	2.3	12.1	12.3
Cycle Q Clear(g_c), s	28.4	7.0	11.1	10.0	0.0	8.0	2.4	28.5	28.6	2.3	12.1	12.3
Prop In Lane	1.00		1.00	1.00		0.54	1.00		0.08	1.00		0.25
Lane Grp Cap(c), veh/h	394	680	535	333	0	523	371	736	764	206	733	736
V/C Ratio(X)	0.68	0.30	0.44	0.12	0.00	0.33	0.21	0.81	0.81	0.37	0.44	0.44
Avail Cap(c_a), veh/h	401	693	545	338	0	532	417	736	764	252	733	736
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	30.7	20.1	21.4	23.7	0.0	20.8	13.9	21.4	21.5	18.5	17.0	17.2
Incr Delay (d2), s/veh	4.5	0.2	0.6	0.2	0.0	0.4	0.3	9.5	9.2	1.1	1.9	1.9
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	6.7	3.6	4.5	0.7	0.0	3.2	1.1	14.7	15.2	1.1	5.8	5.9
LnGrp Delay(d),s/veh	35.2	20.4	22.0	23.8	0.0	21.2	14.2	30.9	30.7	19.6	18.9	19.1
LnGrp LOS	D	C	C	C		C	B	C	C	B	B	B
Approach Vol, veh/h		708			212			1297			722	
Approach Delay, s/veh		26.5			21.7			29.8			19.0	
Approach LOS		C			C			C			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4	5	6		8
Phs Duration (G+Y+Rc), s	8.3	44.5		37.2	8.3	44.5		37.2
Change Period (Y+Rc), s	4.0	6.0		6.0	4.0	6.0		6.0
Max Green Setting (Gmax), s	6.3	35.4		31.8	6.8	35.4		31.8
Max Q Clear Time (g_c+I1), s	4.3	30.6		30.4	4.4	14.3		12.0
Green Ext Time (p_c), s	0.0	4.1		0.8	0.0	14.4		5.9

Intersection Summary	
HCM 2010 Ctrl Delay	25.8
HCM 2010 LOS	C

HCM 2010 Signalized Intersection Summary
323: Fischer-Hallman Rd/Bearinger Rd & Laurelwood Dr

Existing (2019) AM Peak
City of Waterloo TMP

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	283	125	250	26	17	8	113	571	59	15	241	76
Future Volume (veh/h)	283	125	250	26	17	8	113	571	59	15	241	76
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	0.99		0.99	1.00		0.99	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1757	1618	1000	1775	1900	1750	1675	1632	1000	1659	1792	1683
Adj Flow Rate, veh/h	308	136	272	28	18	9	123	621	64	16	262	83
Adj No. of Lanes	1	1	0	1	1	1	1	1	0	1	1	1
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	1	0	0	0	0	0	6	1	1	7	6	4
Cap, veh/h	538	168	336	180	664	515	478	792	82	233	766	609
Arrive On Green	0.35	0.35	0.32	0.35	0.35	0.35	0.06	0.54	0.52	0.43	0.43	0.43
Sat Flow, veh/h	1287	480	961	927	1900	1473	1595	1455	150	671	1792	1425
Grp Volume(v), veh/h	308	0	408	28	18	9	123	0	685	16	262	83
Grp Sat Flow(s),veh/h/ln	1287	0	1441	927	1900	1473	1595	0	1605	671	1792	1425
Q Serve(g_s), s	15.6	0.0	19.5	2.1	0.5	0.3	3.2	0.0	25.6	1.5	7.4	2.7
Cycle Q Clear(g_c), s	16.0	0.0	19.5	21.6	0.5	0.3	3.2	0.0	25.6	18.3	7.4	2.7
Prop In Lane	1.00		0.67	1.00		1.00	1.00		0.09	1.00		1.00
Lane Grp Cap(c), veh/h	538	0	504	180	664	515	478	0	874	233	766	609
V/C Ratio(X)	0.57	0.00	0.81	0.16	0.03	0.02	0.26	0.00	0.78	0.07	0.34	0.14
Avail Cap(c_a), veh/h	549	0	516	188	681	528	482	0	874	233	766	609
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	21.3	0.0	22.9	32.1	16.1	16.0	11.2	0.0	13.7	24.4	14.5	13.1
Incr Delay (d2), s/veh	1.4	0.0	9.2	0.4	0.0	0.0	0.3	0.0	7.0	0.6	1.2	0.5
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	5.7	0.0	9.0	0.6	0.2	0.1	1.4	0.0	12.9	0.3	3.9	1.1
LnGrp Delay(d),s/veh	22.7	0.0	32.1	32.5	16.1	16.0	11.5	0.0	20.7	25.0	15.7	13.6
LnGrp LOS	C		C	C	B	B	B		C	C	B	B
Approach Vol, veh/h		716			55			808			361	
Approach Delay, s/veh		28.1			24.4			19.3			15.6	
Approach LOS		C			C			B			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4	5	6		8
Phs Duration (G+Y+Rc), s		45.0		30.3	8.8	36.2		30.3
Change Period (Y+Rc), s		6.0		6.0	4.0	6.0		6.0
Max Green Setting (Gmax), s		39.0		25.0	5.0	30.0		25.0
Max Q Clear Time (g_c+I1), s		27.6		21.5	5.2	20.3		23.6
Green Ext Time (p_c), s		5.8		1.6	0.0	5.2		0.7

Intersection Summary	
HCM 2010 Ctrl Delay	22.0
HCM 2010 LOS	C

HCM 2010 Signalized Intersection Summary
324: Erbsville Rd & Laurelwood Dr

Existing (2019) AM Peak
City of Waterloo TMP

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	22	232	224	56	140	62	194	279	144	150	261	24
Future Volume (veh/h)	22	232	224	56	140	62	194	279	144	150	261	24
Number	3	8	18	7	4	14	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	0.80		0.69	0.86		0.68	0.97		0.92	0.96		0.90
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1659	1845	1683	1599	1566	1000	1723	1681	1750	1707	1497	1000
Adj Flow Rate, veh/h	22	232	224	56	140	62	194	279	144	150	261	24
Adj No. of Lanes	1	1	1	1	1	0	1	1	1	1	1	0
Peak Hour Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Percent Heavy Veh, %	7	3	4	11	6	6	3	13	0	4	10	10
Cap, veh/h	343	778	418	312	373	165	403	636	515	384	461	42
Arrive On Green	0.42	0.42	0.42	0.42	0.42	0.40	0.10	0.38	0.38	0.07	0.34	0.32
Sat Flow, veh/h	841	1845	991	684	884	392	1641	1681	1364	1625	1336	123
Grp Volume(v), veh/h	22	232	224	56	0	202	194	279	144	150	0	285
Grp Sat Flow(s),veh/h/ln	841	1845	991	684	0	1276	1641	1681	1364	1625	0	1459
Q Serve(g_s), s	1.7	7.5	15.2	5.3	0.0	9.9	6.8	11.1	6.6	5.6	0.0	14.3
Cycle Q Clear(g_c), s	11.5	7.5	15.2	12.8	0.0	9.9	6.8	11.1	6.6	5.6	0.0	14.3
Prop In Lane	1.00		1.00	1.00		0.31	1.00		1.00	1.00		0.08
Lane Grp Cap(c), veh/h	343	778	418	312	0	538	403	636	515	384	0	503
V/C Ratio(X)	0.06	0.30	0.54	0.18	0.00	0.38	0.48	0.44	0.28	0.39	0.00	0.57
Avail Cap(c_a), veh/h	343	779	419	312	0	539	458	636	515	384	0	503
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	21.9	17.2	19.4	21.4	0.0	18.1	18.0	20.9	19.5	18.9	0.0	24.1
Incr Delay (d2), s/veh	0.1	0.2	1.3	0.3	0.0	0.4	0.9	2.2	1.3	0.6	0.0	4.6
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.4	3.8	4.3	1.0	0.0	3.5	3.1	5.5	2.7	2.5	0.0	6.4
LnGrp Delay(d),s/veh	21.9	17.4	20.8	21.7	0.0	18.5	18.9	23.1	20.8	19.6	0.0	28.6
LnGrp LOS	C	B	C	C		B	B	C	C	B		C
Approach Vol, veh/h		478			258			617			435	
Approach Delay, s/veh		19.2			19.2			21.2			25.5	
Approach LOS		B			B			C			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4	5	6		8
Phs Duration (G+Y+Rc), s	10.0	38.0		42.0	13.0	35.0		42.0
Change Period (Y+Rc), s	4.0	6.0		6.0	4.0	6.0		6.0
Max Green Setting (Gmax), s	6.0	32.0		36.0	12.0	26.0		36.0
Max Q Clear Time (g_c+I1), s	7.6	13.1		14.8	8.8	16.3		17.2
Green Ext Time (p_c), s	0.0	4.7		5.8	0.2	3.3		5.6

Intersection Summary	
HCM 2010 Ctrl Delay	21.4
HCM 2010 LOS	C

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	128	103	158	32	329	31	224	377	9	15	448	176
Future Volume (veh/h)	128	103	158	32	329	31	224	377	9	15	448	176
Number	3	8	18	7	4	14	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.99	0.99		0.99	1.00		1.00	1.00		0.99
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1675	1810	1699	1690	1620	1000	1659	1615	1000	1644	1580	1000
Adj Flow Rate, veh/h	128	103	158	32	329	31	224	377	9	15	448	176
Adj No. of Lanes	1	1	1	1	1	0	1	1	0	1	1	0
Peak Hour Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Percent Heavy Veh, %	6	5	3	5	2	2	7	2	2	8	5	5
Cap, veh/h	77	416	329	257	335	32	372	1084	26	569	613	241
Arrive On Green	0.23	0.23	0.23	0.23	0.23	0.22	0.08	0.69	0.68	0.57	0.57	0.57
Sat Flow, veh/h	915	1810	1432	1006	1457	137	1580	1570	37	875	1078	424
Grp Volume(v), veh/h	128	103	158	32	0	360	224	0	386	15	0	624
Grp Sat Flow(s),veh/h/ln	915	1810	1432	1006	0	1595	1580	0	1608	875	0	1502
Q Serve(g_s), s	0.5	4.6	9.6	2.7	0.0	22.5	5.8	0.0	9.8	0.8	0.0	30.6
Cycle Q Clear(g_c), s	23.0	4.6	9.6	7.3	0.0	22.5	5.8	0.0	9.8	0.8	0.0	30.6
Prop In Lane	1.00		1.00	1.00		0.09	1.00		0.02	1.00		0.28
Lane Grp Cap(c), veh/h	77	416	329	257	0	367	372	0	1109	569	0	854
V/C Ratio(X)	1.66	0.25	0.48	0.12	0.00	0.98	0.60	0.00	0.35	0.03	0.00	0.73
Avail Cap(c_a), veh/h	77	416	329	257	0	367	402	0	1109	569	0	854
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	50.0	31.4	33.3	34.4	0.0	38.3	14.9	0.0	6.3	9.5	0.0	15.9
Incr Delay (d2), s/veh	348.1	1.4	4.9	1.0	0.0	42.6	2.2	0.0	0.9	0.1	0.0	5.5
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	9.6	2.5	4.2	0.8	0.0	14.2	3.2	0.0	4.6	0.2	0.0	13.9
LnGrp Delay(d),s/veh	398.1	32.9	38.3	35.4	0.0	80.9	17.1	0.0	7.2	9.5	0.0	21.4
LnGrp LOS	F	C	D	D		F	B		A	A		C
Approach Vol, veh/h		389			392			610			639	
Approach Delay, s/veh		155.2			77.2			10.8			21.1	
Approach LOS		F			E			B			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4	5	6		8
Phs Duration (G+Y+Rc), s		73.0		27.0	12.1	60.9		27.0
Change Period (Y+Rc), s		6.0		6.0	4.0	6.0		6.0
Max Green Setting (Gmax), s		67.0		21.0	10.0	53.0		21.0
Max Q Clear Time (g_c+I1), s		11.8		24.5	7.8	32.6		25.0
Green Ext Time (p_c), s		15.7		0.0	0.4	10.4		0.0

Intersection Summary	
HCM 2010 Ctrl Delay	54.6
HCM 2010 LOS	D

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	255	385	186	93	896	39	351	284	44	60	235	558
Future Volume (veh/h)	255	385	186	93	896	39	351	284	44	60	235	558
Number	3	8	18	7	4	14	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		0.99	0.99		0.98
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1690	1669	1000	1707	1845	1620	1740	1707	1000	1775	1827	1716
Adj Flow Rate, veh/h	283	428	207	103	996	43	390	316	49	67	261	620
Adj No. of Lanes	1	2	0	1	2	1	1	2	0	1	1	1
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	5	6	6	4	3	8	2	4	4	0	4	2
Cap, veh/h	280	755	362	286	1005	393	408	1133	174	386	524	585
Arrive On Green	0.14	0.36	0.35	0.06	0.29	0.29	0.16	0.40	0.39	0.04	0.29	0.27
Sat Flow, veh/h	1610	2080	996	1625	3505	1373	1657	2813	431	1690	1827	1429
Grp Volume(v), veh/h	283	325	310	103	996	43	390	181	184	67	261	620
Grp Sat Flow(s),veh/h/ln	1610	1586	1490	1625	1752	1373	1657	1621	1624	1690	1827	1429
Q Serve(g_s), s	16.4	19.7	20.2	5.4	34.0	2.8	18.8	9.0	9.2	3.4	14.3	32.4
Cycle Q Clear(g_c), s	16.4	19.7	20.2	5.4	34.0	2.8	18.8	9.0	9.2	3.4	14.3	32.4
Prop In Lane	1.00		0.67	1.00		1.00	1.00		0.27	1.00		1.00
Lane Grp Cap(c), veh/h	280	576	541	286	1005	393	408	653	654	386	524	585
V/C Ratio(X)	1.01	0.56	0.57	0.36	0.99	0.11	0.96	0.28	0.28	0.17	0.50	1.06
Avail Cap(c_a), veh/h	280	576	541	297	1005	393	408	653	654	413	524	585
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	35.2	30.6	31.3	29.3	42.7	31.5	28.8	24.1	24.2	29.7	35.6	35.7
Incr Delay (d2), s/veh	56.5	4.0	4.4	0.8	26.4	0.6	33.3	1.1	1.1	0.2	3.4	54.0
Initial Q Delay(d3),s/veh	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	8.7	9.2	9.0	2.5	20.1	1.1	8.1	4.2	4.3	1.6	7.7	28.1
LnGrp Delay(d),s/veh	91.8	34.6	35.7	30.1	69.0	32.1	62.1	25.1	25.3	29.9	39.0	89.7
LnGrp LOS	F	C	D	C	E	C	E	C	C	C	D	F
Approach Vol, veh/h		918			1142			755			948	
Approach Delay, s/veh		52.6			64.1			44.3			71.5	
Approach LOS		D			E			D			E	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	8.9	52.3	20.4	38.4	22.8	38.4	11.2	47.6
Change Period (Y+Rc), s	4.0	6.0	4.0	6.0	4.0	6.0	4.0	6.0
Max Green Setting (Gmax), s	6.3	44.4	16.4	32.4	18.8	32.4	8.0	40.8
Max Q Clear Time (g_c+I1), s	5.4	11.2	18.4	36.0	20.8	34.4	7.4	22.2
Green Ext Time (p_c), s	0.0	16.5	0.0	0.0	0.0	0.0	0.0	14.2

Intersection Summary	
HCM 2010 Ctrl Delay	59.2
HCM 2010 LOS	E

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	244	430	115	82	507	42	155	191	52	47	68	73
Future Volume (veh/h)	244	430	115	82	507	42	155	191	52	47	68	73
Number	1	6	16	5	2	12	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.98	0.99		0.99	0.98		0.98	0.97		0.96
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1757	1776	1683	1775	1679	1000	1740	1720	1000	1707	1611	1000
Adj Flow Rate, veh/h	265	467	125	89	551	46	168	208	57	51	74	79
Adj No. of Lanes	1	2	1	1	2	0	1	2	0	1	2	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	1	7	4	0	6	6	2	3	3	4	5	5
Cap, veh/h	504	1855	770	458	1483	124	334	758	202	224	245	211
Arrive On Green	0.03	0.18	0.18	0.04	0.50	0.48	0.10	0.30	0.28	0.16	0.16	0.16
Sat Flow, veh/h	1674	3374	1400	1690	2979	248	1657	2539	677	989	1531	1316
Grp Volume(v), veh/h	265	467	125	89	295	302	168	132	133	51	74	79
Grp Sat Flow(s),veh/h/ln	1674	1687	1400	1690	1595	1631	1657	1634	1582	989	1531	1316
Q Serve(g_s), s	8.0	13.1	8.3	2.9	12.5	12.6	9.2	6.8	7.2	5.0	4.7	5.9
Cycle Q Clear(g_c), s	8.0	13.1	8.3	2.9	12.5	12.6	9.2	6.8	7.2	5.0	4.7	5.9
Prop In Lane	1.00		1.00	1.00		0.15	1.00		0.43	1.00		1.00
Lane Grp Cap(c), veh/h	504	1855	770	458	794	812	334	488	472	224	245	211
V/C Ratio(X)	0.53	0.25	0.16	0.19	0.37	0.37	0.50	0.27	0.28	0.23	0.30	0.37
Avail Cap(c_a), veh/h	553	1855	770	494	794	812	369	610	591	277	327	281
HCM Platoon Ratio	0.33	0.33	0.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	13.2	25.6	23.7	13.5	17.0	17.1	33.6	29.4	29.9	40.9	40.8	41.3
Incr Delay (d2), s/veh	0.9	0.3	0.5	0.2	1.3	1.3	1.2	0.3	0.3	0.5	0.7	1.1
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	3.8	6.2	3.3	1.4	5.8	5.9	4.3	3.1	3.2	1.4	2.0	2.2
LnGrp Delay(d),s/veh	14.0	25.9	24.1	13.7	18.3	18.4	34.8	29.7	30.2	41.4	41.4	42.4
LnGrp LOS	B	C	C	B	B	B	C	C	C	D	D	D
Approach Vol, veh/h		857			686			433			204	
Approach Delay, s/veh		22.0			17.8			31.9			41.8	
Approach LOS		C			B			C			D	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4	5	6	7	8
Phs Duration (G+Y+Rc), s	14.4	58.8		36.9	8.7	64.5	15.2	21.6
Change Period (Y+Rc), s	4.0	6.0		6.0	4.0	6.0	4.0	6.0
Max Green Setting (Gmax), s	13.6	41.3		39.1	7.0	47.9	13.6	21.5
Max Q Clear Time (g_c+I1), s	10.0	14.6		9.2	4.9	15.1	11.2	7.9
Green Ext Time (p_c), s	0.4	9.8		3.6	0.0	10.6	0.1	2.8

Intersection Summary	
HCM 2010 Ctrl Delay	24.5
HCM 2010 LOS	C

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	125	351	101	215	299	58	117	324	139	97	262	76
Future Volume (veh/h)	125	351	101	215	299	58	117	324	139	97	262	76
Number	3	8	18	7	4	14	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	0.99		0.99	0.99		0.99	0.99		0.98	0.99		0.98
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1740	1683	1000	1675	1693	1000	1628	1827	1651	1707	1776	1606
Adj Flow Rate, veh/h	136	382	110	234	325	63	127	352	151	105	285	83
Adj No. of Lanes	1	2	0	1	2	0	1	2	1	1	2	1
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	3	3	6	5	5	9	4	6	4	7	9
Cap, veh/h	425	867	246	412	1054	202	375	1173	465	336	1140	452
Arrive On Green	0.07	0.35	0.35	0.04	0.13	0.13	0.02	0.11	0.11	0.05	0.34	0.34
Sat Flow, veh/h	1657	2451	697	1595	2689	515	1551	3471	1376	1625	3374	1338
Grp Volume(v), veh/h	136	247	245	234	193	195	127	352	151	105	285	83
Grp Sat Flow(s),veh/h/ln	1657	1599	1549	1595	1608	1595	1551	1736	1376	1625	1687	1338
Q Serve(g_s), s	5.8	13.0	13.3	9.9	12.0	12.2	5.9	10.3	11.1	4.8	6.7	4.8
Cycle Q Clear(g_c), s	5.8	13.0	13.3	9.9	12.0	12.2	5.9	10.3	11.1	4.8	6.7	4.8
Prop In Lane	1.00		0.45	1.00		0.32	1.00		1.00	1.00		1.00
Lane Grp Cap(c), veh/h	425	565	548	412	630	625	375	1173	465	336	1140	452
V/C Ratio(X)	0.32	0.44	0.45	0.57	0.31	0.31	0.34	0.30	0.32	0.31	0.25	0.18
Avail Cap(c_a), veh/h	462	565	548	435	630	625	375	1173	465	336	1140	452
HCM Platoon Ratio	1.00	1.00	1.00	0.33	0.33	0.33	0.33	0.33	0.33	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	21.4	27.2	27.3	21.7	34.3	34.4	24.7	36.9	37.3	23.6	26.3	25.7
Incr Delay (d2), s/veh	0.4	2.5	2.6	1.6	1.3	1.3	0.5	0.7	1.8	0.5	0.5	0.9
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	2.7	6.1	6.1	4.5	5.5	5.6	0.4	5.1	4.5	2.1	3.2	1.9
LnGrp Delay(d),s/veh	21.9	29.6	29.9	23.3	35.6	35.7	25.3	37.6	39.1	24.2	26.9	26.6
LnGrp LOS	C	C	C	C	D	D	C	D	D	C	C	C
Approach Vol, veh/h		628			622			630			473	
Approach Delay, s/veh		28.1			31.0			35.5			26.2	
Approach LOS		C			C			D			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	9.9	41.2	11.8	47.1	9.9	41.2	16.0	42.9
Change Period (Y+Rc), s	4.0	6.0	4.0	6.0	4.0	6.0	4.0	6.0
Max Green Setting (Gmax), s	5.9	33.6	10.3	40.2	5.9	33.6	13.6	36.9
Max Q Clear Time (g_c+I1), s	7.8	13.1	7.8	14.2	7.9	8.7	11.9	15.3
Green Ext Time (p_c), s	0.0	6.1	0.1	6.9	0.0	6.5	0.2	6.4

Intersection Summary	
HCM 2010 Ctrl Delay	30.4
HCM 2010 LOS	C

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	100	384	131	110	596	226	158	652	93	115	614	78
Future Volume (veh/h)	100	384	131	110	596	226	158	652	93	115	614	78
Number	3	8	18	7	4	14	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	0.98		0.93	0.98		1.00	1.00		0.95	0.99		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1644	1759	1667	1740	1702	1000	1599	1845	1606	1690	1731	1000
Adj Flow Rate, veh/h	109	417	142	120	648	0	172	709	101	125	667	0
Adj No. of Lanes	1	2	1	1	2	0	1	2	1	1	2	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	8	8	5	2	4	4	11	3	9	5	2	2
Cap, veh/h	344	1203	626	395	1167	0	327	1262	466	320	1091	0
Arrive On Green	0.03	0.12	0.12	0.11	0.48	0.00	0.11	0.36	0.36	0.03	0.11	0.00
Sat Flow, veh/h	1565	3343	1314	1657	3319	0	1523	3505	1295	1610	3375	0
Grp Volume(v), veh/h	109	417	142	120	648	0	172	709	101	125	667	0
Grp Sat Flow(s),veh/h/ln	1565	1671	1314	1657	1617	0	1523	1752	1295	1610	1644	0
Q Serve(g_s), s	4.2	11.5	8.2	4.4	14.2	0.0	6.9	16.2	5.4	5.0	19.4	0.0
Cycle Q Clear(g_c), s	4.2	11.5	8.2	4.4	14.2	0.0	6.9	16.2	5.4	5.0	19.4	0.0
Prop In Lane	1.00		1.00	1.00		0.00	1.00		1.00	1.00		0.00
Lane Grp Cap(c), veh/h	344	1203	626	395	1167	0	327	1262	466	320	1091	0
V/C Ratio(X)	0.32	0.35	0.23	0.30	0.56	0.00	0.53	0.56	0.22	0.39	0.61	0.00
Avail Cap(c_a), veh/h	345	1203	626	395	1167	0	330	1262	466	320	1091	0
HCM Platoon Ratio	0.33	0.33	0.33	1.33	1.33	1.33	1.00	1.00	1.00	0.33	0.33	0.33
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	0.00
Uniform Delay (d), s/veh	19.2	33.3	22.5	17.1	20.3	0.0	19.5	25.7	22.2	21.1	38.4	0.0
Incr Delay (d2), s/veh	0.5	0.8	0.8	0.4	1.9	0.0	1.5	1.8	1.1	0.8	2.6	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	1.9	5.4	3.1	2.0	6.6	0.0	3.0	8.1	2.1	2.2	9.2	0.0
LnGrp Delay(d),s/veh	19.7	34.0	23.3	17.6	22.2	0.0	21.0	27.5	23.3	21.8	40.9	0.0
LnGrp LOS	B	C	C	B	C		C	C	C	C	D	
Approach Vol, veh/h		668			768			982			792	
Approach Delay, s/veh		29.4			21.5			25.9			37.9	
Approach LOS		C			C			C			D	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	10.0	40.0	9.9	40.1	12.8	37.2	10.0	40.0
Change Period (Y+Rc), s	4.0	6.0	4.0	6.0	4.0	6.0	4.0	6.0
Max Green Setting (Gmax), s	6.0	34.0	6.0	34.0	9.0	31.0	6.0	34.0
Max Q Clear Time (g_c+I1), s	7.0	18.2	6.2	16.2	8.9	21.4	6.4	13.5
Green Ext Time (p_c), s	0.0	9.7	0.0	8.9	0.0	6.7	0.0	9.6

Intersection Summary	
HCM 2010 Ctrl Delay	28.6
HCM 2010 LOS	C

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	230	558	20	16	424	207	4	5	4	50	11	90
Future Volume (veh/h)	230	558	20	16	424	207	4	5	4	50	11	90
Number	1	6	16	5	2	12	3	8	18	7	4	14
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	0.94		0.86	0.93		0.83	0.80		0.66	0.69		0.66
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1757	1629	1000	1775	1608	1000	1183	1650	1000	1690	1580	1000
Adj Flow Rate, veh/h	250	607	22	17	461	225	4	5	4	54	12	98
Adj No. of Lanes	1	2	0	1	2	0	1	1	0	1	1	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	1	9	9	0	14	14	50	0	0	5	0	0
Cap, veh/h	576	2059	75	460	1029	494	162	164	131	277	25	200
Arrive On Green	0.09	0.68	0.67	1.00	1.00	1.00	0.24	0.24	0.23	0.24	0.24	0.23
Sat Flow, veh/h	1674	3028	110	703	1865	895	651	683	546	874	102	835
Grp Volume(v), veh/h	250	310	319	17	376	310	4	0	9	54	0	110
Grp Sat Flow(s),veh/h/ln	1674	1548	1589	703	1528	1232	651	0	1229	874	0	937
Q Serve(g_s), s	6.3	8.0	8.1	0.0	0.0	0.0	0.5	0.0	0.6	5.0	0.0	10.2
Cycle Q Clear(g_c), s	6.3	8.0	8.1	0.0	0.0	0.0	10.7	0.0	0.6	5.6	0.0	10.2
Prop In Lane	1.00		0.07	1.00		0.73	1.00		0.44	1.00		0.89
Lane Grp Cap(c), veh/h	576	1053	1081	460	843	680	162	0	295	277	0	225
V/C Ratio(X)	0.43	0.29	0.30	0.04	0.45	0.46	0.02	0.00	0.03	0.20	0.00	0.49
Avail Cap(c_a), veh/h	662	1053	1081	460	843	680	175	0	320	294	0	244
HCM Platoon Ratio	1.00	1.00	1.00	2.00	2.00	2.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	7.6	6.4	6.4	0.0	0.0	0.0	37.4	0.0	29.3	31.2	0.0	33.1
Incr Delay (d2), s/veh	0.5	0.7	0.7	0.2	1.7	2.2	0.1	0.0	0.0	0.3	0.0	1.6
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	2.9	3.6	3.7	0.0	0.4	0.4	0.1	0.0	0.2	1.2	0.0	2.7
LnGrp Delay(d),s/veh	8.2	7.1	7.1	0.2	1.7	2.2	37.4	0.0	29.3	31.6	0.0	34.8
LnGrp LOS	A	A	A	A	A	A	D		C	C		C
Approach Vol, veh/h		879			703			13			164	
Approach Delay, s/veh		7.4			1.9			31.8			33.7	
Approach LOS		A			A			C			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4		6		8
Phs Duration (G+Y+Rc), s	12.8	59.2		28.0		72.0		28.0
Change Period (Y+Rc), s	4.0	6.0		6.0		6.0		6.0
Max Green Setting (Gmax), s	14.0	46.0		24.0		64.0		24.0
Max Q Clear Time (g_c+I1), s	8.3	2.0		12.2		10.1		12.7
Green Ext Time (p_c), s	0.5	15.2		1.0		16.0		1.0

Intersection Summary	
HCM 2010 Ctrl Delay	7.8
HCM 2010 LOS	A

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	75	497	33	62	553	52	114	237	67	42	208	44
Future Volume (veh/h)	75	497	33	62	553	52	114	237	67	42	208	44
Number	1	6	16	5	2	12	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.99	1.00		0.99	0.99		0.99	0.99		0.99
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1757	1651	1000	1707	1637	1000	1775	1881	1591	1517	1900	1750
Adj Flow Rate, veh/h	82	540	36	67	601	57	124	258	73	46	226	48
Adj No. of Lanes	1	2	0	1	2	0	1	1	1	1	1	1
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	1	8	8	4	8	8	0	1	10	17	0	0
Cap, veh/h	340	1366	91	382	1305	124	373	572	407	271	532	412
Arrive On Green	0.04	0.46	0.44	0.03	0.30	0.29	0.06	0.30	0.30	0.07	0.56	0.56
Sat Flow, veh/h	1674	2983	198	1625	2868	272	1690	1881	1339	1445	1900	1472
Grp Volume(v), veh/h	82	283	293	67	325	333	124	258	73	46	226	48
Grp Sat Flow(s),veh/h/ln	1674	1569	1613	1625	1555	1585	1690	1881	1339	1445	1900	1472
Q Serve(g_s), s	2.7	12.0	12.1	2.2	16.9	17.0	5.4	11.1	4.0	2.3	6.9	1.5
Cycle Q Clear(g_c), s	2.7	12.0	12.1	2.2	16.9	17.0	5.4	11.1	4.0	2.3	6.9	1.5
Prop In Lane	1.00		0.12	1.00		0.17	1.00		1.00	1.00		1.00
Lane Grp Cap(c), veh/h	340	718	738	382	708	721	373	572	407	271	532	412
V/C Ratio(X)	0.24	0.39	0.40	0.18	0.46	0.46	0.33	0.45	0.18	0.17	0.42	0.12
Avail Cap(c_a), veh/h	365	718	738	411	708	721	373	572	407	305	532	412
HCM Platoon Ratio	1.00	1.00	1.00	0.67	0.67	0.67	1.00	1.00	1.00	2.00	2.00	2.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	15.8	17.9	18.1	15.2	24.8	24.9	25.0	28.1	25.6	25.0	17.4	16.2
Incr Delay (d2), s/veh	0.4	1.6	1.6	0.2	2.1	2.1	0.5	2.6	1.0	0.3	2.5	0.6
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	1.3	5.5	5.7	1.0	7.7	7.9	2.5	6.1	1.6	0.9	3.9	0.7
LnGrp Delay(d),s/veh	16.2	19.6	19.6	15.4	27.0	27.0	25.5	30.6	26.6	25.3	19.8	16.8
LnGrp LOS	B	B	B	B	C	C	C	C	C	C	B	B
Approach Vol, veh/h		658			725			455			320	
Approach Delay, s/veh		19.2			25.9			28.6			20.2	
Approach LOS		B			C			C			C	
Timer	1	2	3	4	5	6	7	8				
Assigned Phs	1	2	3	4	5	6	7	8				
Phs Duration (G+Y+Rc), s	8.5	49.5	7.6	34.4	8.2	49.8	10.0	32.0				
Change Period (Y+Rc), s	4.0	6.0	4.0	6.0	4.0	6.0	4.0	6.0				
Max Green Setting (Gmax), s	6.3	42.0	6.0	26.0	6.0	42.0	6.0	26.0				
Max Q Clear Time (g_c+I1), s	14.7	19.0	4.3	13.1	4.2	14.1	7.4	8.9				
Green Ext Time (p_c), s	0.0	10.1	0.0	3.3	0.0	11.0	0.0	3.8				
Intersection Summary												
HCM 2010 Ctrl Delay			23.6									
HCM 2010 LOS			C									

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	100	434	41	86	629	86	46	238	42	75	277	58
Future Volume (veh/h)	100	434	41	86	629	86	46	238	42	75	277	58
Number	1	6	16	5	2	12	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	0.99		0.90	0.95		0.94	0.95		0.89	0.94		0.90
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1690	1649	1000	1757	1707	1000	1455	1712	1000	1723	1693	1000
Adj Flow Rate, veh/h	109	472	45	93	684	93	50	259	46	82	301	63
Adj No. of Lanes	1	2	0	1	2	0	1	2	0	1	2	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	5	6	6	1	4	4	22	4	4	3	4	4
Cap, veh/h	316	1295	123	474	1262	171	263	788	137	334	795	163
Arrive On Green	0.11	0.90	0.86	0.05	0.44	0.42	0.03	0.29	0.27	0.05	0.31	0.29
Sat Flow, veh/h	1610	2861	271	1674	2845	386	1386	2718	471	1641	2604	532
Grp Volume(v), veh/h	109	257	260	93	389	388	50	152	153	82	183	181
Grp Sat Flow(s),veh/h/ln	1610	1566	1566	1674	1621	1609	1386	1626	1562	1641	1608	1528
Q Serve(g_s), s	3.8	2.3	2.5	3.1	17.6	17.7	2.6	7.3	7.7	3.6	8.9	9.4
Cycle Q Clear(g_c), s	3.8	2.3	2.5	3.1	17.6	17.7	2.6	7.3	7.7	3.6	8.9	9.4
Prop In Lane	1.00		0.17	1.00		0.24	1.00		0.30	1.00		0.35
Lane Grp Cap(c), veh/h	316	709	709	474	720	714	263	472	453	334	491	467
V/C Ratio(X)	0.34	0.36	0.37	0.20	0.54	0.54	0.19	0.32	0.34	0.25	0.37	0.39
Avail Cap(c_a), veh/h	355	709	709	495	720	714	298	472	453	350	491	467
HCM Platoon Ratio	2.00	2.00	2.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	15.4	2.7	2.9	14.8	20.4	20.6	25.4	27.8	28.2	24.7	27.2	27.7
Incr Delay (d2), s/veh	0.6	1.4	1.5	0.2	2.9	2.9	0.3	1.8	2.0	0.4	2.2	2.4
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	1.7	1.1	1.2	1.4	8.4	8.5	1.0	3.5	3.6	1.6	4.3	4.3
LnGrp Delay(d),s/veh	16.1	4.2	4.4	15.0	23.3	23.5	25.8	29.6	30.2	25.0	29.4	30.1
LnGrp LOS	B	A	A	B	C	C	C	C	C	C	C	C
Approach Vol, veh/h		626			870			355			446	
Approach Delay, s/veh		6.3			22.5			29.3			28.9	
Approach LOS		A			C			C			C	
Timer	1	2	3	4	5	6	7	8				
Assigned Phs	1	2	3	4	5	6	7	8				
Phs Duration (G+Y+Rc), s	9.6	48.4	9.0	33.0	8.7	49.2	7.5	34.5				
Change Period (Y+Rc), s	4.0	6.0	4.0	6.0	4.0	6.0	4.0	6.0				
Max Green Setting (Gmax), s	8.3	39.0	6.0	27.0	6.0	41.0	6.0	27.0				
Max Q Clear Time (g_c+I1), s	5.8	19.7	5.6	9.7	5.1	4.5	4.6	11.4				
Green Ext Time (p_c), s	0.1	9.7	0.0	4.5	0.0	13.0	0.0	4.3				
Intersection Summary												
HCM 2010 Ctrl Delay			20.4									
HCM 2010 LOS			C									

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	4	668	81	268	1134	0	95	0	261	1	0	3
Future Volume (veh/h)	4	668	81	268	1134	0	95	0	261	1	0	3
Number	5	2	12	1	6	16	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.99	1.00		1.00	0.99		0.98	1.00		0.98
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1775	1810	1651	1690	1723	1000	1599	1542	1000	1000	1403	1000
Adj Flow Rate, veh/h	4	726	88	291	1233	0	103	0	284	1	0	3
Adj No. of Lanes	1	2	1	1	2	0	1	1	0	0	1	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	0	5	6	5	3	3	11	0	0	0	0	0
Cap, veh/h	258	1660	674	562	1915	0	276	0	371	68	18	122
Arrive On Green	0.05	0.97	0.97	0.13	0.58	0.00	0.29	0.00	0.27	0.29	0.00	0.27
Sat Flow, veh/h	1690	3438	1396	1610	3360	0	1201	0	1280	78	62	420
Grp Volume(v), veh/h	4	726	88	291	1233	0	103	0	284	4	0	0
Grp Sat Flow(s),veh/h/ln	1690	1719	1396	1610	1637	0	1201	0	1280	560	0	0
Q Serve(g_s), s	0.1	1.3	0.2	8.2	25.1	0.0	0.0	0.0	20.4	0.1	0.0	0.0
Cycle Q Clear(g_c), s	0.1	1.3	0.2	8.2	25.1	0.0	18.7	0.0	20.4	20.5	0.0	0.0
Prop In Lane	1.00		1.00	1.00		0.00	1.00		1.00	0.25		0.75
Lane Grp Cap(c), veh/h	258	1660	674	562	1915	0	276	0	371	207	0	0
V/C Ratio(X)	0.02	0.44	0.13	0.52	0.64	0.00	0.37	0.00	0.76	0.02	0.00	0.00
Avail Cap(c_a), veh/h	350	1660	674	630	1915	0	276	0	371	207	0	0
HCM Platoon Ratio	2.00	2.00	2.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	0.00	1.00	0.00	1.00	1.00	0.00	0.00
Uniform Delay (d), s/veh	12.9	0.9	0.9	8.5	13.8	0.0	31.9	0.0	33.4	26.8	0.0	0.0
Incr Delay (d2), s/veh	0.0	0.8	0.4	0.7	1.7	0.0	3.8	0.0	13.9	0.2	0.0	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.1	0.6	0.2	3.7	11.8	0.0	2.8	0.0	8.7	0.1	0.0	0.0
LnGrp Delay(d),s/veh	12.9	1.8	1.3	9.2	15.5	0.0	35.7	0.0	47.3	27.0	0.0	0.0
LnGrp LOS	B	A	A	A	B		D		D	C		
Approach Vol, veh/h		818			1524			387			4	
Approach Delay, s/veh		1.8			14.3			44.2			27.0	
Approach LOS		A			B			D			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4	5	6		8
Phs Duration (G+Y+Rc), s	14.7	52.3		33.0	4.5	62.5		33.0
Change Period (Y+Rc), s	4.0	6.0		6.0	4.0	6.0		6.0
Max Green Setting (Gmax), s	15.0	42.0		27.0	6.0	51.0		27.0
Max Q Clear Time (g_c+I1), s	10.2	3.3		22.4	2.1	27.1		22.5
Green Ext Time (p_c), s	0.6	25.6		1.1	0.0	18.1		1.1

Intersection Summary	
HCM 2010 Ctrl Delay	14.8
HCM 2010 LOS	B

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	173	319	63	141	74	87	39	374	397	194	444	86
Future Volume (veh/h)	173	319	63	141	74	87	39	374	397	194	444	86
Number	3	8	18	7	4	14	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		0.99	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1690	1605	1000	1723	1534	1000	1543	1727	1667	1740	1525	1000
Adj Flow Rate, veh/h	173	319	63	141	74	87	39	374	397	194	444	86
Adj No. of Lanes	1	1	0	1	1	0	1	1	1	1	1	0
Peak Hour Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Percent Heavy Veh, %	5	2	2	3	7	7	15	10	5	2	9	9
Cap, veh/h	421	340	67	217	186	218	264	663	506	360	648	126
Arrive On Green	0.08	0.26	0.24	0.08	0.29	0.27	0.38	0.38	0.36	0.09	0.52	0.50
Sat Flow, veh/h	1610	1302	257	1641	643	756	721	1727	1401	1657	1241	240
Grp Volume(v), veh/h	173	0	382	141	0	161	39	374	397	194	0	530
Grp Sat Flow(s),veh/h/ln	1610	0	1559	1641	0	1399	721	1727	1401	1657	0	1481
Q Serve(g_s), s	7.0	0.0	21.6	5.7	0.0	8.4	3.8	15.3	22.7	6.2	0.0	24.0
Cycle Q Clear(g_c), s	7.0	0.0	21.6	5.7	0.0	8.4	15.4	15.3	22.7	6.2	0.0	24.0
Prop In Lane	1.00		0.16	1.00		0.54	1.00		1.00	1.00		0.16
Lane Grp Cap(c), veh/h	421	0	407	217	0	404	264	663	506	360	0	774
V/C Ratio(X)	0.41	0.00	0.94	0.65	0.00	0.40	0.15	0.56	0.78	0.54	0.00	0.69
Avail Cap(c_a), veh/h	421	0	407	244	0	404	264	663	506	444	0	774
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	22.4	0.0	32.7	24.9	0.0	26.2	26.4	21.8	25.6	16.3	0.0	16.1
Incr Delay (d2), s/veh	0.6	0.0	31.7	5.0	0.0	2.9	1.2	3.5	11.5	1.3	0.0	4.9
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.5	0.0	12.8	2.8	0.0	3.6	0.8	7.9	10.4	2.9	0.0	10.8
LnGrp Delay(d),s/veh	23.0	0.0	64.4	29.9	0.0	29.1	27.6	25.3	37.1	17.5	0.0	21.0
LnGrp LOS	C		E	C		C	C	C	D	B		C
Approach Vol, veh/h		555			302			810			724	
Approach Delay, s/veh		51.5			29.5			31.2			20.1	
Approach LOS		D			C			C			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4		6	7	8
Phs Duration (G+Y+Rc), s	12.5	38.5	9.0	30.0		51.0	11.5	27.5
Change Period (Y+Rc), s	4.0	6.0	4.0	6.0		6.0	4.0	6.0
Max Green Setting (Gmax), s	13.0	28.0	5.0	24.0		45.0	9.0	20.0
Max Q Clear Time (g_c+I1), s	9.2	24.7	9.0	10.4		26.0	7.7	23.6
Green Ext Time (p_c), s	0.3	2.4	0.0	3.4		9.3	0.1	0.0

Intersection Summary	
HCM 2010 Ctrl Delay	32.3
HCM 2010 LOS	C

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	76	85	53	71	17	54	15	592	62	72	591	20
Future Volume (veh/h)	76	85	53	71	17	54	15	592	62	72	591	20
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	0.99		0.99	0.99		0.98	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1757	1582	1000	1659	1555	1000	1599	1528	1000	1740	1529	1000
Adj Flow Rate, veh/h	76	85	53	71	17	54	15	592	62	72	591	20
Adj No. of Lanes	1	1	0	1	1	0	1	1	0	1	1	0
Peak Hour Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Percent Heavy Veh, %	1	2	2	7	0	0	11	8	8	2	8	8
Cap, veh/h	273	183	114	211	65	207	478	781	82	336	979	33
Arrive On Green	0.20	0.20	0.20	0.20	0.20	0.20	0.57	0.57	0.57	0.09	1.00	1.00
Sat Flow, veh/h	1232	908	566	1102	324	1029	692	1360	142	1657	1470	50
Grp Volume(v), veh/h	76	0	138	71	0	71	15	0	654	72	0	611
Grp Sat Flow(s),veh/h/ln	1232	0	1475	1102	0	1352	692	0	1502	1657	0	1520
Q Serve(g_s), s	5.0	0.0	7.4	5.5	0.0	4.0	0.8	0.0	29.5	1.5	0.0	0.0
Cycle Q Clear(g_c), s	9.0	0.0	7.4	12.9	0.0	4.0	0.8	0.0	29.5	1.5	0.0	0.0
Prop In Lane	1.00		0.38	1.00		0.76	1.00		0.09	1.00		0.03
Lane Grp Cap(c), veh/h	273	0	297	211	0	272	478	0	863	336	0	1012
V/C Ratio(X)	0.28	0.00	0.47	0.34	0.00	0.26	0.03	0.00	0.76	0.21	0.00	0.60
Avail Cap(c_a), veh/h	381	0	426	307	0	391	478	0	863	351	0	1012
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00	2.00
Upstream Filter(I)	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	34.1	0.0	31.7	37.4	0.0	30.3	8.3	0.0	14.4	11.5	0.0	0.0
Incr Delay (d2), s/veh	0.5	0.0	1.1	0.9	0.0	0.5	0.1	0.0	6.2	0.3	0.0	2.7
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	1.7	0.0	3.1	1.7	0.0	1.5	0.2	0.0	13.7	0.7	0.0	0.8
LnGrp Delay(d),s/veh	34.6	0.0	32.8	38.3	0.0	30.8	8.4	0.0	20.6	11.8	0.0	2.7
LnGrp LOS	C		C	D		C	A		C	B		A
Approach Vol, veh/h		214			142			669			683	
Approach Delay, s/veh		33.5			34.6			20.3			3.6	
Approach LOS		C			C			C			A	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4		6		8
Phs Duration (G+Y+Rc), s	8.2	57.7		24.1		65.9		24.1
Change Period (Y+Rc), s	4.0	6.0		6.0		6.0		6.0
Max Green Setting (Gmax), s	5.0	43.0		26.0		52.0		26.0
Max Q Clear Time (g_c+I1), s	11.5	31.5		11.0		2.0		14.9
Green Ext Time (p_c), s	0.0	7.2		2.0		15.3		1.7

Intersection Summary	
HCM 2010 Ctrl Delay	16.5
HCM 2010 LOS	B

Appendix B

PM Peak Hour Traffic Operations Reports

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	287	863	0	0	390	221	0	0	0	440	0	406
Future Volume (veh/h)	287	863	0	0	390	221	0	0	0	440	0	406
Number	5	2	12	1	6	16	3	8	18	7	4	14
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1740	1618	1000	1000	1618	1716	1000	1520	1000	1740	1618	1000
Adj Flow Rate, veh/h	319	959	0	0	433	0	0	0	0	489	0	451
Adj No. of Lanes	1	1	0	0	1	1	0	1	0	1	1	0
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	480	890	0	0	566	510	0	532	0	670	0	481
Arrive On Green	0.17	0.55	0.00	0.00	0.35	0.00	0.00	0.00	0.00	0.35	0.00	0.35
Sat Flow, veh/h	1657	1618	0	0	1618	1458	0	1520	0	1657	0	1375
Grp Volume(v), veh/h	319	959	0	0	433	0	0	0	0	489	0	451
Grp Sat Flow(s),veh/h/ln	1657	1618	0	0	1618	1458	0	1520	0	1657	0	1375
Q Serve(g_s), s	8.6	44.0	0.0	0.0	19.0	0.0	0.0	0.0	0.0	21.8	0.0	25.4
Cycle Q Clear(g_c), s	8.6	44.0	0.0	0.0	19.0	0.0	0.0	0.0	0.0	21.8	0.0	25.4
Prop In Lane	1.00		0.00	0.00		1.00	0.00		0.00	1.00		1.00
Lane Grp Cap(c), veh/h	480	890	0	0	566	510	0	532	0	670	0	481
V/C Ratio(X)	0.66	1.08	0.00	0.00	0.76	0.00	0.00	0.00	0.00	0.73	0.00	0.94
Avail Cap(c_a), veh/h	480	890	0	0	566	510	0	532	0	670	0	481
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	14.2	18.0	0.0	0.0	23.1	0.0	0.0	0.0	0.0	24.0	0.0	25.1
Incr Delay (d2), s/veh	7.1	53.4	0.0	0.0	9.5	0.0	0.0	0.0	0.0	6.9	0.0	28.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	4.8	32.5	0.0	0.0	9.9	0.0	0.0	0.0	0.0	11.2	0.0	13.3
LnGrp Delay(d),s/veh	21.3	71.4	0.0	0.0	32.6	0.0	0.0	0.0	0.0	30.8	0.0	53.2
LnGrp LOS	C	F			C					C		D
Approach Vol, veh/h		1278			433			0			940	
Approach Delay, s/veh		58.9			32.6			0.0			41.6	
Approach LOS		E			C						D	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4	5	6		8
Phs Duration (G+Y+Rc), s		48.0		32.0	16.0	32.0		32.0
Change Period (Y+Rc), s		6.0		6.0	4.0	6.0		6.0
Max Green Setting (Gmax), s		42.0		26.0	12.0	26.0		26.0
Max Q Clear Time (g_c+I1), s		46.0		27.4	10.6	21.0		0.0
Green Ext Time (p_c), s		0.0		0.0	0.2	3.9		0.0

Intersection Summary	
HCM 2010 Ctrl Delay	48.5
HCM 2010 LOS	D

Intersection	
Int Delay, s/veh	142.5

Movement	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations						
Traffic Vol, veh/h	941	272	238	726	31	219
Future Vol, veh/h	941	272	238	726	31	219
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	-	-	-	0	0
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	90	90	90	90	90	90
Heavy Vehicles, %	2	2	2	2	2	2
Mvmt Flow	1046	302	264	807	34	243

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	1348	0	2129	674
Stage 1	-	-	-	-	1197	-
Stage 2	-	-	-	-	932	-
Critical Hdwy	-	-	4.14	-	6.84	6.94
Critical Hdwy Stg 1	-	-	-	-	5.84	-
Critical Hdwy Stg 2	-	-	-	-	5.84	-
Follow-up Hdwy	-	-	2.22	-	3.52	3.32
Pot Cap-1 Maneuver	-	-	507	-	43	397
Stage 1	-	-	-	-	249	-
Stage 2	-	-	-	-	344	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	507	-	~ 2	397
Mov Cap-2 Maneuver	-	-	-	-	~ 2	-
Stage 1	-	-	-	-	249	-
Stage 2	-	-	-	-	~ 19	-

Approach	EB	WB	NB
HCM Control Delay, s	0	9.1	$ 1348
HCM LOS			F

Minor Lane/Major Mvmt	NBLn1	NBLn2	EBT	EBR	WBL	WBT
Capacity (veh/h)	2	397	-	-	507	-
HCM Lane V/C Ratio	17.222	0.613	-	-	0.522	-
HCM Control Delay (s)	$ 10677.3	27.4	-	-	19.6	5.6
HCM Lane LOS	F	D	-	-	C	A
HCM 95th %tile Q(veh)	6.2	3.9	-	-	3	-

Notes			
~: Volume exceeds capacity	$: Delay exceeds 300s	+: Computation Not Defined	*: All major volume in platoon

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	117	458	49	80	1028	102	110	119	117	349	103	446
Future Volume (veh/h)	117	458	49	80	1028	102	110	119	117	349	103	446
Number	1	6	16	5	2	12	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1740	1740	1000	1740	1740	1000	1740	1863	1716	1740	1740	1000
Adj Flow Rate, veh/h	130	509	54	89	1142	113	122	132	130	388	114	496
Adj No. of Lanes	1	2	0	1	2	0	1	1	1	1	2	0
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	230	1296	137	478	1372	136	212	453	355	454	451	403
Arrive On Green	0.08	0.43	0.43	0.03	0.15	0.15	0.09	0.24	0.24	0.12	0.27	0.27
Sat Flow, veh/h	1657	3018	319	1657	3040	300	1657	1863	1458	1657	1653	1479
Grp Volume(v), veh/h	130	278	285	89	620	635	122	132	130	388	114	496
Grp Sat Flow(s),veh/h/ln	1657	1653	1684	1657	1653	1687	1657	1863	1458	1657	1653	1479
Q Serve(g_s), s	4.6	12.7	12.8	2.9	40.1	40.2	5.8	6.3	8.1	13.0	5.9	30.0
Cycle Q Clear(g_c), s	4.6	12.7	12.8	2.9	40.1	40.2	5.8	6.3	8.1	13.0	5.9	30.0
Prop In Lane	1.00		0.19	1.00		0.18	1.00		1.00	1.00		1.00
Lane Grp Cap(c), veh/h	230	710	723	478	746	762	212	453	355	454	451	403
V/C Ratio(X)	0.57	0.39	0.39	0.19	0.83	0.83	0.57	0.29	0.37	0.85	0.25	1.23
Avail Cap(c_a), veh/h	267	710	723	478	746	762	261	508	398	454	451	403
HCM Platoon Ratio	1.00	1.00	1.00	0.33	0.33	0.33	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	23.3	21.5	21.5	14.0	42.7	42.8	29.7	33.9	34.6	32.1	31.2	40.0
Incr Delay (d2), s/veh	2.2	1.6	1.6	0.9	10.4	10.4	2.4	0.4	0.6	14.6	0.3	123.3
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	2.2	6.1	6.3	1.4	20.6	21.0	2.8	3.3	3.4	7.6	2.7	26.0
LnGrp Delay(d),s/veh	25.5	23.1	23.2	14.9	53.2	53.2	32.2	34.2	35.2	46.8	31.5	163.3
LnGrp LOS	C	C	C	B	D	D	C	C	D	D	C	F
Approach Vol, veh/h		693			1344			384			998	
Approach Delay, s/veh		23.6			50.6			33.9			102.9	
Approach LOS		C			D			C			F	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	10.6	53.7	15.0	30.8	13.0	51.2	11.8	34.0
Change Period (Y+Rc), s	4.0	6.0	4.0	6.0	4.0	6.0	4.0	6.0
Max Green Setting (Gmax), s	9.0	42.0	11.0	28.0	9.0	42.0	11.0	28.0
Max Q Clear Time (g_c+I1), s	6.6	42.2	15.0	10.1	4.9	14.8	7.8	32.0
Green Ext Time (p_c), s	0.1	0.0	0.0	6.3	0.1	16.8	0.1	0.0

Intersection Summary	
HCM 2010 Ctrl Delay	58.5
HCM 2010 LOS	E

Intersection	
Int Delay, s/veh	9

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	0	24	4	136	54	58	5	168	109	38	210	5
Future Vol, veh/h	0	24	4	136	54	58	5	168	109	38	210	5
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Stop	Stop	Stop	Stop	Stop	Stop	Free	Free	Free	Free	Free	Free
RT Channelized	-	-	None	-	-	None	-	-	None	-	-	None
Storage Length	-	-	-	-	-	-	-	-	-	-	-	-
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	90	90	90	90	90	90	90	90	90	90	90	90
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	0	27	4	151	60	64	6	187	121	42	233	6

Major/Minor	Minor2			Minor1			Major1			Major2		
Conflicting Flow All	642	640	236	596	583	248	239	0	0	308	0	0
Stage 1	320	320	-	260	260	-	-	-	-	-	-	-
Stage 2	322	320	-	336	323	-	-	-	-	-	-	-
Critical Hdwy	7.12	6.52	6.22	7.12	6.52	6.22	4.12	-	-	4.12	-	-
Critical Hdwy Stg 1	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Critical Hdwy Stg 2	6.12	5.52	-	6.12	5.52	-	-	-	-	-	-	-
Follow-up Hdwy	3.518	4.018	3.318	3.518	4.018	3.318	2.218	-	-	2.218	-	-
Pot Cap-1 Maneuver	387	393	803	415	424	791	1328	-	-	1253	-	-
Stage 1	692	652	-	745	693	-	-	-	-	-	-	-
Stage 2	690	652	-	678	650	-	-	-	-	-	-	-
Platoon blocked, %								-	-		-	-
Mov Cap-1 Maneuver	305	375	803	377	405	791	1328	-	-	1253	-	-
Mov Cap-2 Maneuver	305	375	-	377	405	-	-	-	-	-	-	-
Stage 1	688	627	-	741	689	-	-	-	-	-	-	-
Stage 2	575	648	-	620	625	-	-	-	-	-	-	-

Approach	EB	WB	NB	SB
HCM Control Delay, s	14.6	26.3	0.1	1.2
HCM LOS	B	D		

Minor Lane/Major Mvmt	NBL	NBT	NBR	EBLn1	WBLn1	SBL	SBT	SBR
Capacity (veh/h)	1328	-	-	406	437	1253	-	-
HCM Lane V/C Ratio	0.004	-	-	0.077	0.631	0.034	-	-
HCM Control Delay (s)	7.7	0	-	14.6	26.3	8	0	-
HCM Lane LOS	A	A	-	B	D	A	A	-
HCM 95th %tile Q(veh)	0	-	-	0.2	4.2	0.1	-	-

Intersection	
Int Delay, s/veh	3.3

Movement	EBT	EBR	WBL	WBT	NBL	NBR
Lane Configurations						
Traffic Vol, veh/h	128	13	119	209	16	65
Future Vol, veh/h	128	13	119	209	16	65
Conflicting Peds, #/hr	0	0	0	0	0	0
Sign Control	Free	Free	Free	Free	Stop	Stop
RT Channelized	-	None	-	None	-	None
Storage Length	-	-	-	-	0	-
Veh in Median Storage, #	0	-	-	0	0	-
Grade, %	0	-	-	0	0	-
Peak Hour Factor	90	90	90	90	90	90
Heavy Vehicles, %	2	2	2	2	2	2
Mvmt Flow	142	14	132	232	18	72

Major/Minor	Major1		Major2		Minor1	
Conflicting Flow All	0	0	156	0	645	149
Stage 1	-	-	-	-	149	-
Stage 2	-	-	-	-	496	-
Critical Hdwy	-	-	4.12	-	6.42	6.22
Critical Hdwy Stg 1	-	-	-	-	5.42	-
Critical Hdwy Stg 2	-	-	-	-	5.42	-
Follow-up Hdwy	-	-	2.218	-	3.518	3.318
Pot Cap-1 Maneuver	-	-	1424	-	437	898
Stage 1	-	-	-	-	879	-
Stage 2	-	-	-	-	612	-
Platoon blocked, %	-	-		-		
Mov Cap-1 Maneuver	-	-	1424	-	391	898
Mov Cap-2 Maneuver	-	-	-	-	391	-
Stage 1	-	-	-	-	879	-
Stage 2	-	-	-	-	547	-

Approach	EB	WB	NB
HCM Control Delay, s	0	2.8	10.8
HCM LOS			B

Minor Lane/Major Mvmt	NBLn1	EBT	EBR	WBL	WBT
Capacity (veh/h)	715	-	-	1424	-
HCM Lane V/C Ratio	0.126	-	-	0.093	-
HCM Control Delay (s)	10.8	-	-	7.8	0
HCM Lane LOS	B	-	-	A	A
HCM 95th %tile Q(veh)	0.4	-	-	0.3	-

Intersection	
Intersection Delay, s/veh	12.6
Intersection LOS	B

Approach	EB	WB	NB	SB
Entry Lanes	1	1	1	1
Conflicting Circle Lanes	1	1	1	1
Adj Approach Flow, veh/h	336	762	136	130
Demand Flow Rate, veh/h	343	777	139	133
Vehicles Circulating, veh/h	237	62	352	748
Vehicles Exiting, veh/h	644	429	228	91
Follow-Up Headway, s	3.186	3.186	3.186	3.186
Ped Vol Crossing Leg, #/h	0	0	0	0
Ped Cap Adj	1.000	1.000	1.000	1.000
Approach Delay, s/veh	8.6	15.9	6.5	10.4
Approach LOS	A	C	A	B

Lane	Left	Left	Left	Left
Designated Moves	LTR	LTR	LTR	LTR
Assumed Moves	LTR	LTR	LTR	LTR
RT Channelized				
Lane Util	1.000	1.000	1.000	1.000
Critical Headway, s	5.193	5.193	5.193	5.193
Entry Flow, veh/h	343	777	139	133
Cap Entry Lane, veh/h	892	1062	795	535
Entry HV Adj Factor	0.980	0.980	0.975	0.978
Flow Entry, veh/h	336	762	136	130
Cap Entry, veh/h	874	1041	775	523
V/C Ratio	0.385	0.732	0.175	0.249
Control Delay, s/veh	8.6	15.9	6.5	10.4
LOS	A	C	A	B
95th %tile Queue, veh	2	7	1	1

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	0	0	0	114	923	186	232	973	0	0	952	162
Future Volume (veh/h)	0	0	0	114	923	186	232	973	0	0	952	162
Number				7	4	14	5	2	12	1	6	16
Initial Q (Qb), veh				0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)				1.00		0.99	1.00		1.00	1.00		0.98
Parking Bus, Adj				1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln				1000	1667	1000	1757	1827	0	0	1726	1000
Adj Flow Rate, veh/h				124	1003	202	252	1058	0	0	1035	176
Adj No. of Lanes				0	4	0	1	2	0	0	2	0
Peak Hour Factor				0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %				0	4	0	1	4	0	0	3	3
Cap, veh/h				168	1455	298	343	2013	0	0	1196	203
Arrive On Green				0.32	0.32	0.32	0.13	0.58	0.00	0.00	0.43	0.43
Sat Flow, veh/h				524	4548	930	1674	3563	0	0	2884	475
Grp Volume(v), veh/h				388	616	324	252	1058	0	0	606	605
Grp Sat Flow(s),veh/h/ln				1641	1434	1493	1674	1736	0	0	1639	1633
Q Serve(g_s), s				16.9	14.9	15.1	6.0	14.7	0.0	0.0	26.8	27.0
Cycle Q Clear(g_c), s				16.9	14.9	15.1	6.0	14.7	0.0	0.0	26.8	27.0
Prop In Lane				0.32		0.62	1.00		0.00	0.00		0.29
Lane Grp Cap(c), veh/h				525	918	478	343	2013	0	0	701	698
V/C Ratio(X)				0.74	0.67	0.68	0.74	0.53	0.00	0.00	0.86	0.87
Avail Cap(c_a), veh/h				525	918	478	389	2013	0	0	701	698
HCM Platoon Ratio				1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)				1.00	1.00	1.00	1.00	1.00	0.00	0.00	1.00	1.00
Uniform Delay (d), s/veh				24.2	23.6	23.6	15.9	10.1	0.0	0.0	20.8	20.8
Incr Delay (d2), s/veh				9.0	3.9	7.6	6.2	1.0	0.0	0.0	13.4	13.7
Initial Q Delay(d3),s/veh				0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln				8.9	6.4	7.2	3.3	7.2	0.0	0.0	14.7	14.8
LnGrp Delay(d),s/veh				33.3	27.5	31.2	22.2	11.1	0.0	0.0	34.2	34.5
LnGrp LOS				C	C	C	C	B			C	C
Approach Vol, veh/h					1329			1310			1211	
Approach Delay, s/veh					30.1			13.3			34.4	
Approach LOS					C			B			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4	5	6		
Phs Duration (G+Y+Rc), s		50.4		29.6	12.2	38.2		
Change Period (Y+Rc), s		6.0		6.0	4.0	6.0		
Max Green Setting (Gmax), s		44.4		23.6	10.4	30.0		
Max Q Clear Time (g_c+I1), s		16.7		18.9	8.0	29.0		
Green Ext Time (p_c), s		21.8		3.5	0.3	1.0		

Intersection Summary	
HCM 2010 Ctrl Delay	25.7
HCM 2010 LOS	C

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	211	463	100	18	225	66	112	809	78	91	719	156
Future Volume (veh/h)	211	463	100	18	225	66	112	809	78	91	719	156
Number	3	8	18	7	4	14	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.99	1.00		0.99	1.00		0.99	1.00		0.99
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1000	1624	1000	1000	1606	1000	1757	1611	1000	1557	1631	1000
Adj Flow Rate, veh/h	234	514	111	20	250	73	124	899	87	101	799	173
Adj No. of Lanes	0	2	0	0	2	0	1	2	0	1	2	0
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	2	2	2	1	1	1	1	1	1	14	1	1
Cap, veh/h	329	695	161	76	857	271	173	1221	118	160	1096	237
Arrive On Green	0.32	0.32	0.32	0.48	0.48	0.48	0.43	0.43	0.43	0.43	0.43	0.43
Sat Flow, veh/h	555	1455	337	66	1794	568	543	2817	273	475	2530	548
Grp Volume(v), veh/h	393	0	466	169	0	174	124	489	497	101	489	483
Grp Sat Flow(s),veh/h/ln	932	0	1416	1071	0	1357	543	1531	1559	475	1549	1529
Q Serve(g_s), s	30.5	0.0	25.9	1.7	0.0	6.9	15.5	23.9	23.9	15.1	23.5	23.5
Cycle Q Clear(g_c), s	37.4	0.0	25.9	27.5	0.0	6.9	39.0	23.9	23.9	39.0	23.5	23.5
Prop In Lane	0.60		0.24	0.12		0.42	1.00		0.17	1.00		0.36
Lane Grp Cap(c), veh/h	509	0	676	556	0	648	173	663	675	160	671	662
V/C Ratio(X)	0.77	0.00	0.69	0.30	0.00	0.27	0.72	0.74	0.74	0.63	0.73	0.73
Avail Cap(c_a), veh/h	509	0	676	556	0	648	173	663	675	160	671	662
HCM Platoon Ratio	0.67	0.67	0.67	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	32.0	0.0	24.8	14.6	0.0	14.1	39.2	21.2	21.2	39.0	21.1	21.1
Incr Delay (d2), s/veh	10.8	0.0	5.7	1.4	0.0	1.0	22.2	7.2	7.0	17.5	6.8	6.9
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	10.9	0.0	11.2	2.7	0.0	2.7	4.1	11.4	11.5	3.3	11.3	11.2
LnGrp Delay(d),s/veh	42.8	0.0	30.4	16.0	0.0	15.1	61.4	28.4	28.3	56.6	27.9	28.0
LnGrp LOS	D		C	B		B	E	C	C	E	C	C
Approach Vol, veh/h		859			343			1110			1073	
Approach Delay, s/veh		36.1			15.6			32.0			30.7	
Approach LOS		D			B			C			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		8
Phs Duration (G+Y+Rc), s		43.0		47.0		43.0		47.0
Change Period (Y+Rc), s		6.0		6.0		6.0		6.0
Max Green Setting (Gmax), s		37.0		41.0		37.0		41.0
Max Q Clear Time (g_c+I1), s		41.0		29.5		41.0		39.4
Green Ext Time (p_c), s		0.0		6.8		0.0		1.2

Intersection Summary	
HCM 2010 Ctrl Delay	31.0
HCM 2010 LOS	C

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	161	203	22	159	253	33	19	610	165	12	643	81
Future Volume (veh/h)	161	203	22	159	253	33	19	610	165	12	643	81
Number	3	8	18	7	4	14	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.98	0.99		0.98	1.00		0.97	1.00		0.96
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1757	1644	1000	1775	1639	1000	1659	1549	1000	1775	1562	1000
Adj Flow Rate, veh/h	179	226	24	177	281	37	21	678	183	13	714	90
Adj No. of Lanes	1	1	0	1	1	0	1	1	0	1	1	0
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	1	0	0	0	0	0	7	8	8	0	6	6
Cap, veh/h	324	565	60	383	548	72	127	598	161	90	594	75
Arrive On Green	0.39	0.39	0.36	0.39	0.39	0.36	0.02	0.51	0.49	0.44	0.44	0.41
Sat Flow, veh/h	993	1458	155	1064	1415	186	1580	1167	315	609	1353	171
Grp Volume(v), veh/h	179	0	250	177	0	318	21	0	861	13	0	804
Grp Sat Flow(s),veh/h/ln	993	0	1612	1064	0	1601	1580	0	1482	609	0	1524
Q Serve(g_s), s	13.5	0.0	9.0	11.6	0.0	12.2	0.6	0.0	41.0	0.0	0.0	35.1
Cycle Q Clear(g_c), s	25.6	0.0	9.0	20.6	0.0	12.2	0.6	0.0	41.0	35.1	0.0	35.1
Prop In Lane	1.00		0.10	1.00		0.12	1.00		0.21	1.00		0.11
Lane Grp Cap(c), veh/h	324	0	625	383	0	621	127	0	759	90	0	669
V/C Ratio(X)	0.55	0.00	0.40	0.46	0.00	0.51	0.17	0.00	1.13	0.14	0.00	1.20
Avail Cap(c_a), veh/h	336	0	645	396	0	640	208	0	759	90	0	669
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	28.5	0.0	17.8	25.2	0.0	18.8	19.4	0.0	19.7	40.0	0.0	22.5
Incr Delay (d2), s/veh	1.8	0.0	0.4	0.9	0.0	0.7	0.6	0.0	76.2	3.3	0.0	104.6
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	8.8	0.0	4.0	3.5	0.0	5.4	0.3	0.0	32.7	0.4	0.0	34.1
LnGrp Delay(d),s/veh	30.3	0.0	18.2	26.1	0.0	19.5	20.0	0.0	95.9	43.3	0.0	127.2
LnGrp LOS	C		B	C		B	C		F	D		F
Approach Vol, veh/h		429			495			882			817	
Approach Delay, s/veh		23.3			21.8			94.1			125.9	
Approach LOS		C			C			F			F	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4	5	6		8
Phs Duration (G+Y+Rc), s		45.0		35.0	5.9	39.1		35.0
Change Period (Y+Rc), s		6.0		6.0	4.0	6.0		6.0
Max Green Setting (Gmax), s		38.0		30.0	6.0	28.0		30.0
Max Q Clear Time (g_c+I1), s		43.0		22.6	2.6	37.1		27.6
Green Ext Time (p_c), s		0.0		3.6	0.0	0.0		1.4

Intersection Summary	
HCM 2010 Ctrl Delay	78.8
HCM 2010 LOS	E

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	48	594	21	38	485	74	3	267	111	10	244	65
Future Volume (veh/h)	48	594	21	38	485	74	3	267	111	10	244	65
Number	3	8	18	7	4	14	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	0.99		0.95	1.00		1.00	0.99		0.94	0.98		0.96
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1723	1618	1000	1757	1845	1667	1707	1682	1000	1723	1681	1000
Adj Flow Rate, veh/h	48	594	21	38	485	0	3	267	111	10	244	65
Adj No. of Lanes	1	1	0	1	1	1	1	2	0	1	2	0
Peak Hour Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Percent Heavy Veh, %	3	2	2	1	3	5	4	7	7	3	6	6
Cap, veh/h	384	775	27	223	922	708	345	774	310	316	903	234
Arrive On Green	0.50	0.50	0.48	0.67	0.67	0.00	0.00	0.35	0.33	0.01	0.36	0.34
Sat Flow, veh/h	833	1550	55	759	1845	1417	1625	2184	875	1641	2490	647
Grp Volume(v), veh/h	48	0	615	38	485	0	3	193	185	10	154	155
Grp Sat Flow(s),veh/h/ln	833	0	1604	759	1845	1417	1625	1598	1461	1641	1597	1539
Q Serve(g_s), s	3.5	0.0	28.0	3.6	12.2	0.0	0.1	8.0	8.6	0.4	6.1	6.5
Cycle Q Clear(g_c), s	15.7	0.0	28.0	31.6	12.2	0.0	0.1	8.0	8.6	0.4	6.1	6.5
Prop In Lane	1.00		0.03	1.00		1.00	1.00		0.60	1.00		0.42
Lane Grp Cap(c), veh/h	384	0	802	223	922	708	345	566	518	316	579	558
V/C Ratio(X)	0.13	0.00	0.77	0.17	0.53	0.00	0.01	0.34	0.36	0.03	0.27	0.28
Avail Cap(c_a), veh/h	384	0	802	223	922	708	465	566	518	387	579	558
HCM Platoon Ratio	1.00	1.00	1.00	1.33	1.33	1.33	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	19.3	0.0	18.3	24.1	9.6	0.0	20.1	21.3	22.0	19.9	20.2	20.6
Incr Delay (d2), s/veh	0.7	0.0	6.9	1.6	2.1	0.0	0.0	1.6	1.9	0.0	1.1	1.2
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.9	0.0	13.8	0.9	6.6	0.0	0.1	3.8	3.7	0.2	2.9	2.9
LnGrp Delay(d),s/veh	19.9	0.0	25.2	25.7	11.7	0.0	20.1	23.0	23.9	19.9	21.4	21.9
LnGrp LOS	B		C	C	B		C	C	C	B	C	C
Approach Vol, veh/h		663			523			381			319	
Approach Delay, s/veh		24.8			12.7			23.4			21.6	
Approach LOS		C			B			C			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4	5	6		8
Phs Duration (G+Y+Rc), s	5.1	35.9		49.0	4.4	36.6		49.0
Change Period (Y+Rc), s	4.0	6.0		6.0	4.0	6.0		6.0
Max Green Setting (Gmax), s	5.0	26.0		43.0	7.0	24.0		43.0
Max Q Clear Time (g_c+I1), s	2.4	10.6		33.6	2.1	8.5		30.0
Green Ext Time (p_c), s	0.0	4.5		5.8	0.0	4.5		7.3

Intersection Summary	
HCM 2010 Ctrl Delay	20.6
HCM 2010 LOS	C

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	216	1	100	4	3	4	154	489	1	1	865	188
Future Volume (veh/h)	216	1	100	4	3	4	154	489	1	1	865	188
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1000	1618	980	1775	1631	1000	1000	1607	1000	1000	1618	1000
Adj Flow Rate, veh/h	240	1	100	4	3	4	154	543	1	1	961	209
Adj No. of Lanes	0	1	1	1	1	0	0	2	0	0	2	0
Peak Hour Factor	0.90	1.00	1.00	1.00	1.00	0.90	1.00	0.90	1.00	0.90	0.90	0.90
Percent Heavy Veh, %	0	0	2	0	0	0	2	2	2	2	2	2
Cap, veh/h	535	2	308	349	235	313	148	817	2	45	1304	283
Arrive On Green	0.37	0.37	0.00	0.37	0.37	0.37	0.00	0.53	0.53	0.36	0.36	0.36
Sat Flow, veh/h	1204	5	833	1227	635	846	133	1541	3	0	2461	534
Grp Volume(v), veh/h	241	0	100	4	0	7	214	0	484	632	0	539
Grp Sat Flow(s),veh/h/ln	1209	0	833	1227	0	1481	214	0	1462	1617	0	1378
Q Serve(g_s), s	12.5	0.0	9.6	0.2	0.0	0.2	15.0	0.0	18.6	0.0	0.0	27.4
Cycle Q Clear(g_c), s	12.7	0.0	9.6	12.9	0.0	0.2	42.4	0.0	18.6	27.3	0.0	27.4
Prop In Lane	1.00		1.00	1.00		0.57	0.72		0.00	0.00		0.39
Lane Grp Cap(c), veh/h	537	0	308	349	0	548	191	0	775	902	0	730
V/C Ratio(X)	0.45	0.00	0.32	0.01	0.00	0.01	1.12	0.00	0.62	0.70	0.00	0.74
Avail Cap(c_a), veh/h	537	0	308	349	0	548	191	0	775	902	0	730
HCM Platoon Ratio	1.00	1.00	0.00	1.00	1.00	1.00	0.00	1.00	1.00	0.67	0.67	0.67
Upstream Filter(I)	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	20.0	0.0	30.0	25.0	0.0	16.0	47.9	0.0	13.2	20.9	0.0	21.0
Incr Delay (d2), s/veh	2.7	0.0	2.8	0.1	0.0	0.0	101.8	0.0	3.8	4.5	0.0	6.6
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	4.6	0.0	2.5	0.1	0.0	0.1	9.6	0.0	8.2	13.3	0.0	11.7
LnGrp Delay(d),s/veh	22.7	0.0	32.8	25.0	0.0	16.0	149.8	0.0	17.0	25.4	0.0	27.6
LnGrp LOS	C		C	C		B	F		B	C		C
Approach Vol, veh/h		341			11			698			1171	
Approach Delay, s/veh		25.6			19.3			57.7			26.4	
Approach LOS		C			B			E			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		8
Phs Duration (G+Y+Rc), s		46.4		33.6		46.4		33.6
Change Period (Y+Rc), s		6.0		6.0		6.0		6.0
Max Green Setting (Gmax), s		40.4		27.6		30.0		27.6
Max Q Clear Time (g_c+I1), s		44.4		14.7		29.4		14.9
Green Ext Time (p_c), s		0.0		1.8		0.6		1.8

Intersection Summary	
HCM 2010 Ctrl Delay	36.1
HCM 2010 LOS	D

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	235	589	157	53	473	333	117	629	60	240	935	240
Future Volume (veh/h)	235	589	157	53	473	333	117	629	60	240	935	240
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.99	1.00		0.98	1.00		0.99	1.00		0.99
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1740	1726	1000	1614	1716	1000	1707	1697	1000	1740	1827	1716
Adj Flow Rate, veh/h	255	640	171	58	514	362	127	684	65	261	1016	261
Adj No. of Lanes	1	2	0	1	2	0	1	2	0	1	2	1
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	2	10	3	3	4	5	5	2	4	2
Cap, veh/h	207	943	252	181	607	427	207	971	92	318	1304	545
Arrive On Green	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sat Flow, veh/h	1657	2553	681	1537	1819	1279	1625	2975	282	1657	3471	1449
Grp Volume(v), veh/h	255	411	400	58	461	415	127	370	379	261	1016	261
Grp Sat Flow(s),veh/h/ln	1657	1640	1595	1537	1631	1467	1625	1613	1645	1657	1736	1449
Q Serve(g_s), s	8.1	27.6	27.6	2.8	31.1	31.1	5.7	25.3	25.3	10.9	32.2	19.8
Cycle Q Clear(g_c), s	8.1	27.6	27.6	2.8	31.1	31.1	5.7	25.3	25.3	10.9	32.2	19.8
Prop In Lane	1.00		0.43	1.00		0.87	1.00		0.17	1.00		1.00
Lane Grp Cap(c), veh/h	207	606	589	181	544	490	207	526	537	318	1304	545
V/C Ratio(X)	1.23	0.68	0.68	0.32	0.85	0.85	0.61	0.70	0.71	0.82	0.78	0.48
Avail Cap(c_a), veh/h	207	606	589	237	544	490	341	526	537	372	1304	545
HCM Platoon Ratio	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	31.9	48.5	48.5	27.8	52.2	52.2	29.6	49.7	49.7	28.3	50.4	44.2
Incr Delay (d2), s/veh	139.9	6.0	6.2	1.0	15.0	16.5	2.9	7.7	7.6	12.1	4.6	3.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	10.6	1.0	1.0	0.5	2.3	2.2	1.5	1.1	1.1	4.0	16.4	0.5
LnGrp Delay(d),s/veh	171.9	54.5	54.7	28.8	67.2	68.8	32.5	57.4	57.3	40.4	55.1	47.2
LnGrp LOS	F	D	D	C	E	E	C	E	E	D	E	D
Approach Vol, veh/h		1066			934			876			1538	
Approach Delay, s/veh		82.6			65.5			53.7			51.3	
Approach LOS		F			E			D			D	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	7.3	39.9	8.2	44.6	11.9	45.3	12.1	40.7
Change Period (Y+Rc), s	4.0	6.0	4.0	6.0	4.0	6.0	4.0	6.0
Max Green Setting (Gmax), s	16.9	30.3	8.1	34.7	16.9	30.3	8.1	34.7
Max Q Clear Time (g_c+I1), s	12.9	27.3	4.8	29.6	7.7	34.2	10.1	33.1
Green Ext Time (p_c), s	0.4	2.7	0.0	4.1	0.3	0.0	0.0	1.4

Intersection Summary	
HCM 2010 Ctrl Delay	62.3
HCM 2010 LOS	E

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	44	772	124	98	818	14	108	84	105	71	99	90
Future Volume (veh/h)	44	772	124	98	818	14	108	84	105	71	99	90
Number	1	6	16	5	2	12	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.77	1.00		0.78	0.96		0.93	0.94		0.92
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1757	1716	1000	1757	1676	1000	1628	1628	1000	1775	1881	1549
Adj Flow Rate, veh/h	48	839	135	107	889	15	117	91	114	77	108	98
Adj No. of Lanes	1	2	0	1	2	0	1	1	0	1	1	1
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	1	3	3	1	6	6	9	3	3	0	1	13
Cap, veh/h	237	1279	206	231	1569	26	348	230	288	278	496	389
Arrive On Green	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sat Flow, veh/h	1674	2689	433	1674	3187	54	1551	632	791	1055	1881	1212
Grp Volume(v), veh/h	48	509	465	107	444	460	117	0	205	77	108	98
Grp Sat Flow(s),veh/h/ln	1674	1631	1491	1674	1592	1649	1551	0	1423	1055	1881	1212
Q Serve(g_s), s	1.7	34.3	34.3	3.6	30.7	30.7	6.0	0.0	15.8	8.0	6.3	8.3
Cycle Q Clear(g_c), s	1.7	34.3	34.3	3.6	30.7	30.7	6.0	0.0	15.8	12.9	6.3	8.3
Prop In Lane	1.00		0.29	1.00		0.03	1.00		0.56	1.00		1.00
Lane Grp Cap(c), veh/h	237	776	709	231	784	812	348	0	517	278	496	389
V/C Ratio(X)	0.20	0.66	0.66	0.46	0.57	0.57	0.34	0.00	0.40	0.28	0.22	0.25
Avail Cap(c_a), veh/h	285	776	709	251	784	812	348	0	517	278	496	389
HCM Platoon Ratio	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	19.4	46.0	46.0	22.0	43.3	43.3	29.1	0.0	42.9	50.4	43.7	38.7
Incr Delay (d2), s/veh	0.4	4.3	4.7	1.4	3.0	2.9	0.6	0.0	2.3	2.5	1.0	1.5
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.5	0.9	0.9	1.4	0.6	0.6	0.4	0.0	6.6	2.5	0.1	2.9
LnGrp Delay(d),s/veh	19.8	50.3	50.7	23.5	46.2	46.1	29.7	0.0	45.2	52.8	44.7	40.2
LnGrp LOS	B	D	D	C	D	D	C		D	D	D	D
Approach Vol, veh/h		1022			1011			322			283	
Approach Delay, s/veh		49.1			43.8			39.6			45.4	
Approach LOS		D			D			D			D	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4	5	6	7	8
Phs Duration (G+Y+Rc), s	7.8	58.2		44.0	9.7	56.3	11.0	33.0
Change Period (Y+Rc), s	4.0	6.0		6.0	4.0	6.0	4.0	6.0
Max Green Setting (Gmax), s	7.8	49.0		38.0	7.0	49.0	7.0	27.0
Max Q Clear Time (g_c+I1), s	3.7	32.7		17.8	5.6	36.3	8.0	14.9
Green Ext Time (p_c), s	0.0	12.1		3.2	0.0	9.8	0.0	2.6

Intersection Summary	
HCM 2010 Ctrl Delay	45.5
HCM 2010 LOS	D

Movement	EBL	EBR	NBL	NBT	SBT	SBR
Lane Configurations						
Traffic Volume (veh/h)	255	188	44	255	253	104
Future Volume (veh/h)	255	188	44	255	253	104
Number	7	14	5	2	6	16
Initial Q (Qb), veh	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00	1.00	1.00			1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1599	1716	1000	1553	1584	1000
Adj Flow Rate, veh/h	255	188	44	255	253	104
Adj No. of Lanes	1	1	0	2	2	0
Peak Hour Factor	1.00	1.00	1.00	1.00	1.00	1.00
Percent Heavy Veh, %	11	2	7	7	3	3
Cap, veh/h	277	265	230	1305	1246	498
Arrive On Green	0.00	0.00	0.00	0.00	0.00	0.00
Sat Flow, veh/h	1523	1458	290	2270	2180	840
Grp Volume(v), veh/h	255	188	150	149	179	178
Grp Sat Flow(s),veh/h/ln	1523	1458	1147	1342	1505	1436
Q Serve(g_s), s	13.4	10.3	3.6	8.9	9.5	9.9
Cycle Q Clear(g_c), s	13.4	10.3	13.5	8.9	9.5	9.9
Prop In Lane	1.00	1.00	0.29			0.59
Lane Grp Cap(c), veh/h	277	265	739	796	893	852
V/C Ratio(X)	0.92	0.71	0.20	0.19	0.20	0.21
Avail Cap(c_a), veh/h	666	638	739	796	893	852
HCM Platoon Ratio	0.00	0.00	0.00	0.00	0.00	0.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	39.4	37.9	22.2	20.7	21.0	21.2
Incr Delay (d2), s/veh	12.2	3.5	0.6	0.5	0.5	0.6
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.9	0.3	0.1	0.1	0.1	0.1
LnGrp Delay(d),s/veh	51.6	41.4	22.8	21.2	21.5	21.8
LnGrp LOS	D	D	C	C	C	C
Approach Vol, veh/h	443			299	357	
Approach Delay, s/veh	47.3			22.0	21.7	
Approach LOS	D			C	C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		
Phs Duration (G+Y+Rc), s		56.5		23.5		56.5		
Change Period (Y+Rc), s		6.0		6.0		6.0		
Max Green Setting (Gmax), s		30.0		38.0		30.0		
Max Q Clear Time (g_c+I1), s		15.5		15.4		11.9		
Green Ext Time (p_c), s		4.1		2.1		4.6		

Intersection Summary	
HCM 2010 Ctrl Delay	32.1
HCM 2010 LOS	C

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	45	1040	171	95	807	76	95	208	78	174	334	100
Future Volume (veh/h)	45	1040	171	95	807	76	95	208	78	174	334	100
Number	1	6	16	5	2	12	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.93	1.00		0.96	0.99		0.96	0.99		0.97
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1775	1693	1000	1723	1708	1000	1757	1613	1000	1723	1827	1750
Adj Flow Rate, veh/h	49	1130	186	103	877	83	103	226	85	189	363	109
Adj No. of Lanes	1	2	0	1	2	0	1	1	0	1	1	1
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	0	5	5	3	4	4	1	2	2	3	4	0
Cap, veh/h	223	1254	205	165	1411	134	218	287	108	221	489	470
Arrive On Green	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sat Flow, veh/h	1690	2732	447	1641	2984	282	1674	1103	415	1641	1827	1438
Grp Volume(v), veh/h	49	663	653	103	477	483	103	0	311	189	363	109
Grp Sat Flow(s),veh/h/ln	1690	1608	1571	1641	1623	1643	1674	0	1518	1641	1827	1438
Q Serve(g_s), s	1.6	41.2	41.6	3.4	29.4	29.4	4.6	0.0	20.5	7.0	19.9	7.0
Cycle Q Clear(g_c), s	1.6	41.2	41.6	3.4	29.4	29.4	4.6	0.0	20.5	7.0	19.9	7.0
Prop In Lane	1.00		0.28	1.00		0.17	1.00		0.27	1.00		1.00
Lane Grp Cap(c), veh/h	223	738	721	165	767	777	218	0	395	221	489	470
V/C Ratio(X)	0.22	0.90	0.91	0.63	0.62	0.62	0.47	0.00	0.79	0.86	0.74	0.23
Avail Cap(c_a), veh/h	279	738	721	196	767	777	231	0	395	221	489	470
HCM Platoon Ratio	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	19.2	47.7	47.8	24.7	41.1	41.1	29.9	0.0	47.2	34.7	46.5	34.3
Incr Delay (d2), s/veh	0.5	15.9	17.1	4.6	3.8	3.7	1.6	0.0	14.7	26.4	9.7	1.2
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.5	3.3	3.4	1.5	0.8	0.8	0.7	0.0	1.6	3.7	1.3	2.9
LnGrp Delay(d),s/veh	19.7	63.6	65.0	29.2	44.8	44.8	31.5	0.0	61.9	61.1	56.3	35.5
LnGrp LOS	B	E	E	C	D	D	C		E	E	E	D
Approach Vol, veh/h		1365			1063			414			661	
Approach Delay, s/veh		62.7			43.3			54.3			54.2	
Approach LOS		E			D			D			D	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	7.7	51.3	11.0	30.0	9.1	49.9	10.2	30.8
Change Period (Y+Rc), s	4.0	6.0	4.0	6.0	4.0	6.0	4.0	6.0
Max Green Setting (Gmax), s	7.0	42.0	7.0	24.0	7.0	42.0	7.0	24.0
Max Q Clear Time (g_c+I1), s	3.6	31.4	9.0	22.5	5.4	43.6	6.6	21.9
Green Ext Time (p_c), s	0.0	9.4	0.0	0.8	0.0	0.0	0.0	1.1

Intersection Summary	
HCM 2010 Ctrl Delay	54.2
HCM 2010 LOS	D

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	114	764	286	188	472	207	197	579	198	231	661	103
Future Volume (veh/h)	114	764	286	188	472	207	197	579	198	231	661	103
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.98	1.00		0.99	1.00		0.98	1.00		0.98
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1707	1731	1000	1757	1863	1683	1707	1719	1000	1723	1745	1000
Adj Flow Rate, veh/h	124	830	311	204	513	225	214	629	215	251	718	112
Adj No. of Lanes	1	2	0	1	1	1	1	2	0	1	2	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	4	2	2	1	2	4	4	3	3	3	2	2
Cap, veh/h	249	932	348	214	782	594	221	671	229	215	808	126
Arrive On Green	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sat Flow, veh/h	1625	2330	871	1674	1863	1414	1625	2380	813	1641	2868	447
Grp Volume(v), veh/h	124	585	556	204	513	225	214	431	413	251	415	415
Grp Sat Flow(s),veh/h/ln	1625	1644	1556	1674	1863	1414	1625	1633	1560	1641	1658	1657
Q Serve(g_s), s	5.0	39.2	39.3	8.4	30.3	17.5	10.0	29.1	29.1	10.0	27.5	27.6
Cycle Q Clear(g_c), s	5.0	39.2	39.3	8.4	30.3	17.5	10.0	29.1	29.1	10.0	27.5	27.6
Prop In Lane	1.00		0.56	1.00		1.00	1.00		0.52	1.00		0.27
Lane Grp Cap(c), veh/h	249	658	623	214	782	594	221	460	440	215	467	467
V/C Ratio(X)	0.50	0.89	0.89	0.95	0.66	0.38	0.97	0.94	0.94	1.17	0.89	0.89
Avail Cap(c_a), veh/h	252	658	623	214	782	594	221	460	440	215	467	467
HCM Platoon Ratio	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	24.4	52.6	52.6	30.8	47.1	40.7	33.6	54.0	54.0	33.5	53.3	53.3
Incr Delay (d2), s/veh	1.5	16.6	17.6	48.4	4.3	1.8	51.2	28.9	30.0	114.7	21.4	21.6
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	1.4	3.0	3.0	2.9	0.9	0.3	5.2	16.9	3.7	6.8	2.8	15.5
LnGrp Delay(d),s/veh	25.9	69.2	70.2	79.3	51.3	42.5	84.8	82.9	84.1	148.1	74.7	74.8
LnGrp LOS	C	E	E	E	D	D	F	F	F	F	E	E
Approach Vol, veh/h		1265			942			1058			1081	
Approach Delay, s/veh		65.4			55.3			83.7			91.8	
Approach LOS		E			E			F			F	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	14.0	35.0	13.0	48.0	14.0	35.0	10.8	50.2
Change Period (Y+Rc), s	4.0	6.0	4.0	6.0	4.0	6.0	4.0	6.0
Max Green Setting (Gmax), s	10.0	29.0	9.0	42.0	10.0	29.0	7.0	44.0
Max Q Clear Time (g_c+I1), s	12.0	31.1	10.4	41.3	12.0	29.6	7.0	32.3
Green Ext Time (p_c), s	0.0	0.0	0.0	0.7	0.0	0.0	0.0	9.0

Intersection Summary	
HCM 2010 Ctrl Delay	74.2
HCM 2010 LOS	E

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	150	538	25	313	915	9	11	279	172	15	694	301
Future Volume (veh/h)	150	538	25	313	915	9	11	279	172	15	694	301
Number	1	6	16	5	2	12	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.95	0.99		1.00	1.00		0.99	1.00		0.99
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1723	1742	1000	1740	1740	1000	1775	1863	1716	1740	1810	1483
Adj Flow Rate, veh/h	163	598	27	348	1017	10	12	303	191	17	754	327
Adj No. of Lanes	1	2	0	1	2	0	1	1	1	1	1	1
Peak Hour Factor	0.92	0.90	0.92	0.90	0.90	0.90	0.92	0.92	0.90	0.90	0.92	0.92
Percent Heavy Veh, %	3	2	2	2	2	2	0	2	2	2	5	18
Cap, veh/h	212	913	41	439	1253	12	88	845	654	356	821	542
Arrive On Green	0.06	0.28	0.27	0.17	0.37	0.37	0.44	0.45	0.45	0.45	0.45	0.44
Sat Flow, veh/h	1641	3217	145	1657	3355	33	495	1863	1441	838	1810	1245
Grp Volume(v), veh/h	163	307	318	348	501	526	12	303	191	17	754	327
Grp Sat Flow(s),veh/h/ln	1641	1655	1708	1657	1653	1734	495	1863	1441	838	1810	1245
Q Serve(g_s), s	7.0	18.0	18.0	15.4	30.0	30.0	2.6	11.7	9.2	1.5	42.9	22.1
Cycle Q Clear(g_c), s	7.0	18.0	18.0	15.4	30.0	30.0	45.5	11.7	9.2	13.2	42.9	22.1
Prop In Lane	1.00		0.08	1.00		0.02	1.00		1.00	1.00		1.00
Lane Grp Cap(c), veh/h	212	469	484	439	618	648	88	845	654	356	821	542
V/C Ratio(X)	0.77	0.65	0.66	0.79	0.81	0.81	0.14	0.36	0.29	0.05	0.92	0.60
Avail Cap(c_a), veh/h	212	469	484	439	618	648	88	845	654	356	821	542
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	32.9	34.7	34.8	22.6	31.0	31.0	51.4	19.6	18.9	23.9	28.1	23.8
Incr Delay (d2), s/veh	18.1	7.0	6.8	10.9	11.1	10.6	3.2	1.2	1.1	0.3	16.9	4.9
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	2.8	9.1	9.4	8.3	15.5	16.2	0.4	6.3	3.9	0.4	25.2	8.3
LnGrp Delay(d),s/veh	51.0	41.6	41.5	33.6	42.1	41.6	54.6	20.8	20.1	24.2	45.1	28.7
LnGrp LOS	D	D	D	C	D	D	D	C	C	C	D	C
Approach Vol, veh/h		788			1375			506			1098	
Approach Delay, s/veh		43.5			39.7			21.3			39.9	
Approach LOS		D			D			C			D	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4	5	6		8
Phs Duration (G+Y+Rc), s	11.0	45.1		53.9	20.9	35.2		53.9
Change Period (Y+Rc), s	4.0	6.0		6.0	4.0	6.0		6.0
Max Green Setting (Gmax), s	7.0	39.1		47.9	16.9	29.2		47.9
Max Q Clear Time (g_c+I1), s	19.5	32.0		47.5	17.4	20.0		44.9
Green Ext Time (p_c), s	0.0	5.6		0.3	0.0	6.9		2.4

Intersection Summary	
HCM 2010 Ctrl Delay	38.1
HCM 2010 LOS	D

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	131	439	76	154	1087	149	187	421	72	303	416	239
Future Volume (veh/h)	131	439	76	154	1087	149	187	421	72	303	416	239
Number	3	8	18	7	4	14	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.99	1.00		0.99	1.00		0.98	1.00		0.98
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1740	1750	1000	1675	1792	1716	1675	1690	1000	1644	1677	1000
Adj Flow Rate, veh/h	131	439	76	154	1087	149	187	421	72	303	416	239
Adj No. of Lanes	1	2	0	1	2	1	1	2	0	2	2	0
Peak Hour Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Percent Heavy Veh, %	2	1	1	6	6	2	6	5	5	8	4	4
Cap, veh/h	197	1028	177	366	1277	544	305	792	134	414	629	357
Arrive On Green	0.07	0.36	0.35	0.08	0.38	0.38	0.10	0.29	0.27	0.14	0.32	0.31
Sat Flow, veh/h	1657	2835	488	1595	3406	1450	1595	2739	465	3037	1947	1106
Grp Volume(v), veh/h	131	256	259	154	1087	149	187	245	248	303	340	315
Grp Sat Flow(s),veh/h/ln	1657	1662	1660	1595	1703	1450	1595	1606	1597	1518	1593	1459
Q Serve(g_s), s	6.1	13.9	14.2	7.4	35.2	8.6	10.0	15.4	15.7	11.5	22.0	22.6
Cycle Q Clear(g_c), s	6.1	13.9	14.2	7.4	35.2	8.6	10.0	15.4	15.7	11.5	22.0	22.6
Prop In Lane	1.00		0.29	1.00		1.00	1.00		0.29	1.00		0.76
Lane Grp Cap(c), veh/h	197	603	602	366	1277	544	305	464	462	414	515	471
V/C Ratio(X)	0.66	0.43	0.43	0.42	0.85	0.27	0.61	0.53	0.54	0.73	0.66	0.67
Avail Cap(c_a), veh/h	198	603	602	400	1277	544	381	464	462	582	515	471
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	28.9	28.8	29.1	23.0	34.4	26.1	28.5	35.8	36.2	49.7	35.0	35.8
Incr Delay (d2), s/veh	9.1	2.2	2.2	0.8	7.3	1.2	2.0	4.3	4.4	2.9	6.5	7.4
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	3.3	6.8	6.9	3.3	17.7	3.6	4.5	7.4	7.5	5.0	10.6	10.0
LnGrp Delay(d),s/veh	37.9	31.0	31.4	23.8	41.7	27.4	30.5	40.1	40.6	52.6	41.5	43.2
LnGrp LOS	D	C	C	C	D	C	C	D	D	D	D	D
Approach Vol, veh/h		646			1390			680			958	
Approach Delay, s/veh		32.6			38.2			37.6			45.5	
Approach LOS		C			D			D			D	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	20.4	38.7	12.0	49.0	16.3	42.8	13.5	47.5
Change Period (Y+Rc), s	6.0	6.0	4.0	6.0	4.0	6.0	4.0	6.0
Max Green Setting (Gmax), s	21.0	26.0	8.0	43.0	18.0	31.0	12.0	39.0
Max Q Clear Time (g_c+I1), s	13.5	17.7	8.1	37.2	12.0	24.6	9.4	16.2
Green Ext Time (p_c), s	0.9	4.8	0.0	4.8	0.4	3.9	0.1	14.5

Intersection Summary	
HCM 2010 Ctrl Delay	39.0
HCM 2010 LOS	D

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	94	301	67	159	272	41	83	481	210	26	429	89
Future Volume (veh/h)	94	301	67	159	272	41	83	481	210	26	429	89
Number	3	8	18	7	4	14	1	6	16	5	2	12
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1628	1577	1000	1675	1581	1000	1000	1554	1000	1000	1598	1000
Adj Flow Rate, veh/h	94	301	67	159	272	41	83	481	210	26	429	89
Adj No. of Lanes	1	1	0	1	1	0	0	2	0	0	2	0
Peak Hour Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Percent Heavy Veh, %	9	3	3	6	5	5	6	6	6	3	3	3
Cap, veh/h	273	450	100	232	483	73	169	882	383	91	1245	253
Arrive On Green	0.36	0.36	0.33	0.36	0.36	0.33	1.00	1.00	1.00	0.54	0.54	0.51
Sat Flow, veh/h	928	1249	278	908	1342	202	211	1634	710	77	2306	468
Grp Volume(v), veh/h	94	0	368	159	0	313	394	0	380	284	0	260
Grp Sat Flow(s),veh/h/ln	928	0	1527	908	0	1545	1270	0	1285	1483	0	1368
Q Serve(g_s), s	7.2	0.0	16.3	12.5	0.0	13.0	1.8	0.0	0.0	0.0	0.0	8.8
Cycle Q Clear(g_c), s	20.3	0.0	16.3	28.8	0.0	13.0	10.6	0.0	0.0	8.0	0.0	8.8
Prop In Lane	1.00		0.18	1.00		0.13	0.21		0.55	0.09		0.34
Lane Grp Cap(c), veh/h	273	0	550	232	0	556	740	0	694	850	0	739
V/C Ratio(X)	0.34	0.00	0.67	0.69	0.00	0.56	0.53	0.00	0.55	0.33	0.00	0.35
Avail Cap(c_a), veh/h	273	0	550	232	0	556	740	0	694	850	0	739
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00	2.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	28.7	0.0	21.8	34.4	0.0	20.7	0.0	0.0	0.0	10.3	0.0	10.7
Incr Delay (d2), s/veh	3.4	0.0	6.4	15.3	0.0	4.1	2.7	0.0	3.1	1.1	0.0	1.3
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	2.1	0.0	7.8	4.5	0.0	6.1	0.8	0.0	0.6	3.7	0.0	3.6
LnGrp Delay(d),s/veh	32.1	0.0	28.1	49.8	0.0	24.7	2.8	0.0	3.1	11.4	0.0	12.0
LnGrp LOS	C		C	D		C	A		A	B		B
Approach Vol, veh/h		462			472			774			544	
Approach Delay, s/veh		28.9			33.2			2.9			11.7	
Approach LOS		C			C			A			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		8
Phs Duration (G+Y+Rc), s		47.2		32.8		47.2		32.8
Change Period (Y+Rc), s		6.0		6.0		6.0		6.0
Max Green Setting (Gmax), s		41.2		26.8		41.2		26.8
Max Q Clear Time (g_c+I1), s		10.8		30.8		12.6		22.3
Green Ext Time (p_c), s		12.6		0.0		12.3		2.6

Intersection Summary	
HCM 2010 Ctrl Delay	16.7
HCM 2010 LOS	B

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	277	185	2	88	348	125	3	307	84	50	451	622
Future Volume (veh/h)	277	185	2	88	348	125	3	307	84	50	451	622
Number	5	2	12	1	6	16	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1723	1775	1000	1707	1757	962	1775	1720	1000	1757	1810	1577
Adj Flow Rate, veh/h	301	201	2	96	378	136	3	334	91	54	490	676
Adj No. of Lanes	1	1	1	1	1	1	1	2	0	1	2	1
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	3	0	0	4	1	4	0	3	3	1	5	11
Cap, veh/h	368	664	318	479	545	253	214	862	231	339	1410	709
Arrive On Green	0.12	0.37	0.37	0.06	0.31	0.31	0.34	0.34	0.34	0.03	0.41	0.41
Sat Flow, veh/h	1641	1775	849	1625	1757	816	457	2547	684	1674	3438	1337
Grp Volume(v), veh/h	301	201	2	96	378	136	3	212	213	54	490	676
Grp Sat Flow(s),veh/h/ln	1641	1775	849	1625	1757	816	457	1634	1597	1674	1719	1337
Q Serve(g_s), s	12.0	8.0	0.1	4.0	18.9	13.8	0.5	9.9	10.2	2.0	9.8	41.0
Cycle Q Clear(g_c), s	12.0	8.0	0.1	4.0	18.9	13.8	3.1	9.9	10.2	2.0	9.8	41.0
Prop In Lane	1.00		1.00	1.00		1.00	1.00		0.43	1.00		1.00
Lane Grp Cap(c), veh/h	368	664	318	479	545	253	214	553	540	339	1410	709
V/C Ratio(X)	0.82	0.30	0.01	0.20	0.69	0.54	0.01	0.38	0.39	0.16	0.35	0.95
Avail Cap(c_a), veh/h	368	664	318	486	545	253	214	553	540	386	1410	709
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	22.5	22.1	19.6	21.4	30.3	28.6	23.8	25.1	25.2	20.0	20.3	22.3
Incr Delay (d2), s/veh	13.6	1.2	0.0	0.2	7.1	8.0	0.0	0.4	0.5	0.2	0.1	23.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	6.8	4.1	0.0	1.8	10.2	3.7	0.1	4.5	4.6	1.0	4.7	22.2
LnGrp Delay(d),s/veh	36.1	23.2	19.7	21.6	37.4	36.5	23.9	25.6	25.7	20.2	20.4	45.4
LnGrp LOS	D	C	B	C	D	D	C	C	C	C	C	D
Approach Vol, veh/h		504			610			428			1220	
Approach Delay, s/veh		30.9			34.8			25.6			34.2	
Approach LOS		C			C			C			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6		8
Phs Duration (G+Y+Rc), s	9.6	43.4	7.1	39.9	16.0	37.0		47.0
Change Period (Y+Rc), s	4.0	6.0	4.0	6.0	4.0	6.0		6.0
Max Green Setting (Gmax), s	6.0	37.0	6.0	31.0	12.0	31.0		41.0
Max Q Clear Time (g_c+I1), s	6.0	10.0	4.0	12.2	14.0	20.9		43.0
Green Ext Time (p_c), s	0.0	5.4	0.0	11.0	0.0	3.5		0.0

Intersection Summary	
HCM 2010 Ctrl Delay	32.4
HCM 2010 LOS	C

Intersection	
Int Delay, s/veh	9.1

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	3	6	17	53	8	91	21	446	129	162	556	17
Future Vol, veh/h	3	6	17	53	8	91	21	446	129	162	556	17
Conflicting Peds, #/hr	0	0	0	0	0	0	0	0	0	0	0	0
Sign Control	Stop	Stop	Stop	Stop	Stop	Stop	Free	Free	Free	Free	Free	Free
RT Channelized	-	-	None	-	-	None	-	-	None	-	-	None
Storage Length	-	-	-	-	-	0	-	-	-	-	-	-
Veh in Median Storage, #	-	0	-	-	0	-	-	0	-	-	0	-
Grade, %	-	0	-	-	0	-	-	0	-	-	0	-
Peak Hour Factor	90	90	90	90	90	90	90	90	90	90	90	90
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	3	7	19	59	9	101	23	496	143	180	618	19

Major/Minor	Minor2			Minor1			Major1			Major2		
Conflicting Flow All	1287	1673	319	1287	1611	320	637	0	0	639	0	0
Stage 1	988	988	-	614	614	-	-	-	-	-	-	-
Stage 2	299	685	-	673	997	-	-	-	-	-	-	-
Critical Hdwy	7.54	6.54	6.94	7.54	6.54	6.94	4.14	-	-	4.14	-	-
Critical Hdwy Stg 1	6.54	5.54	-	6.54	5.54	-	-	-	-	-	-	-
Critical Hdwy Stg 2	6.54	5.54	-	6.54	5.54	-	-	-	-	-	-	-
Follow-up Hdwy	3.52	4.02	3.32	3.52	4.02	3.32	2.22	-	-	2.22	-	-
Pot Cap-1 Maneuver	121	95	677	121	103	676	943	-	-	941	-	-
Stage 1	265	323	-	446	481	-	-	-	-	-	-	-
Stage 2	685	447	-	411	320	-	-	-	-	-	-	-
Platoon blocked, %								-	-		-	-
Mov Cap-1 Maneuver	70	64	677	81	70	676	943	-	-	941	-	-
Mov Cap-2 Maneuver	70	64	-	81	70	-	-	-	-	-	-	-
Stage 1	255	227	-	429	462	-	-	-	-	-	-	-
Stage 2	549	430	-	273	225	-	-	-	-	-	-	-

Approach	EB	WB	NB	SB
HCM Control Delay, s	32.2	69	0.5	2.8
HCM LOS	D	F		

Minor Lane/Major Mvmt	NBL	NBT	NBR	EBLn1	WBLn1	WBLn2	SBL	SBT	SBR
Capacity (veh/h)	943	-	-	161	79	676	941	-	-
HCM Lane V/C Ratio	0.025	-	-	0.179	0.858	0.15	0.191	-	-
HCM Control Delay (s)	8.9	0.2	-	32.2	155	11.3	9.7	0.9	-
HCM Lane LOS	A	A	-	D	F	B	A	A	-
HCM 95th %tile Q(veh)	0.1	-	-	0.6	4.4	0.5	0.7	-	-

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	131	0	45	0	0	0	41	532	0	0	646	116
Future Volume (veh/h)	131	0	45	0	0	0	41	532	0	0	646	116
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1740	1618	1000	1000	1520	1000	1000	1618	1000	1000	1618	1716
Adj Flow Rate, veh/h	146	0	50	0	0	0	46	591	0	0	718	129
Adj No. of Lanes	1	1	0	0	1	0	0	2	0	0	2	1
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	2	2	2	2	2	2	2	2	2	2	2	2
Cap, veh/h	423	0	242	0	267	0	162	1796	0	0	2083	988
Arrive On Green	0.18	0.00	0.18	0.00	0.00	0.00	0.68	0.68	0.00	0.00	0.68	0.68
Sat Flow, veh/h	1657	0	1375	0	1520	0	127	2724	0	0	3154	1458
Grp Volume(v), veh/h	146	0	50	0	0	0	321	316	0	0	718	129
Grp Sat Flow(s),veh/h/ln	1657	0	1375	0	1520	0	1379	1398	0	0	1537	1458
Q Serve(g_s), s	4.3	0.0	1.7	0.0	0.0	0.0	0.0	5.1	0.0	0.0	5.4	1.7
Cycle Q Clear(g_c), s	4.3	0.0	1.7	0.0	0.0	0.0	4.3	5.1	0.0	0.0	5.4	1.7
Prop In Lane	1.00		1.00	0.00		0.00	0.14		0.00	0.00		1.00
Lane Grp Cap(c), veh/h	423	0	242	0	267	0	1010	948	0	0	2083	988
V/C Ratio(X)	0.35	0.00	0.21	0.00	0.00	0.00	0.32	0.33	0.00	0.00	0.34	0.13
Avail Cap(c_a), veh/h	800	0	554	0	612	0	1010	948	0	0	2083	988
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	1.00	0.00	0.00	0.00	1.00	1.00	0.00	0.00	1.00	1.00
Uniform Delay (d), s/veh	20.3	0.0	19.2	0.0	0.0	0.0	3.5	3.7	0.0	0.0	3.7	3.1
Incr Delay (d2), s/veh	0.5	0.0	0.4	0.0	0.0	0.0	0.8	0.9	0.0	0.0	0.5	0.3
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	2.0	0.0	0.7	0.0	0.0	0.0	2.1	2.2	0.0	0.0	2.3	0.8
LnGrp Delay(d),s/veh	20.8	0.0	19.7	0.0	0.0	0.0	4.4	4.6	0.0	0.0	4.2	3.4
LnGrp LOS	C		B				A	A			A	A
Approach Vol, veh/h		196			0			637			847	
Approach Delay, s/veh		20.5			0.0			4.5			4.0	
Approach LOS		C						A			A	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		8
Phs Duration (G+Y+Rc), s		41.0		13.6		41.0		13.6
Change Period (Y+Rc), s		6.0		6.0		6.0		6.0
Max Green Setting (Gmax), s		35.0		20.0		35.0		20.0
Max Q Clear Time (g_c+I1), s		7.1		6.3		7.4		0.0
Green Ext Time (p_c), s		13.9		0.7		13.9		0.0

Intersection Summary	
HCM 2010 Ctrl Delay	6.1
HCM 2010 LOS	A

Intersection	
Intersection Delay, s/veh	20.5
Intersection LOS	C

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Vol, veh/h	48	42	121	22	25	11	267	294	41	12	258	133
Future Vol, veh/h	48	42	121	22	25	11	267	294	41	12	258	133
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Heavy Vehicles, %	2	2	2	2	2	2	2	2	2	2	2	2
Mvmt Flow	53	47	134	24	28	12	297	327	46	13	287	148
Number of Lanes	0	1	1	0	1	0	1	1	0	0	1	0

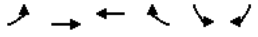
Approach	EB	WB	NB	SB
Opposing Approach	WB	EB	SB	NB
Opposing Lanes	1	2	1	2
Conflicting Approach Left	SB	NB	EB	WB
Conflicting Lanes Left	1	2	2	1
Conflicting Approach Right	NB	SB	WB	EB
Conflicting Lanes Right	2	1	1	2
HCM Control Delay	12.3	12.6	18.8	28.5
HCM LOS	B	B	C	D

Lane	NBLn1	NBLn2	EBLn1	EBLn2	WBLn1	SBLn1
Vol Left, %	100%	0%	53%	0%	38%	3%
Vol Thru, %	0%	88%	47%	0%	43%	64%
Vol Right, %	0%	12%	0%	100%	19%	33%
Sign Control	Stop	Stop	Stop	Stop	Stop	Stop
Traffic Vol by Lane	267	335	90	121	58	403
LT Vol	267	0	48	0	22	12
Through Vol	0	294	42	0	25	258
RT Vol	0	41	0	121	11	133
Lane Flow Rate	297	372	100	134	64	448
Geometry Grp	7	7	7	7	6	6
Degree of Util (X)	0.56	0.641	0.217	0.255	0.146	0.782
Departure Headway (Hd)	6.794	6.197	7.822	6.829	8.161	6.287
Convergence, Y/N	Yes	Yes	Yes	Yes	Yes	Yes
Cap	528	577	456	522	442	573
Service Time	4.577	3.981	5.618	4.624	6.161	4.365
HCM Lane V/C Ratio	0.563	0.645	0.219	0.257	0.145	0.782
HCM Control Delay	18	19.5	12.8	12	12.6	28.5
HCM Lane LOS	C	C	B	B	B	D
HCM 95th-tile Q	3.4	4.6	0.8	1	0.5	7.3

Movement	EBL	EBR	NBL	NBT	SBT	SBR
Lane Configurations						
Traffic Volume (veh/h)	149	14	17	443	901	314
Future Volume (veh/h)	149	14	17	443	901	314
Number	7	14	5	2	6	16
Initial Q (Qb), veh	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00	1.00	1.00			1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1740	1683	1644	1863	1863	1716
Adj Flow Rate, veh/h	166	15	18	492	1001	349
Adj No. of Lanes	1	1	1	2	2	1
Peak Hour Factor	0.90	0.92	0.92	0.90	0.90	0.90
Percent Heavy Veh, %	2	4	8	2	2	2
Cap, veh/h	230	198	316	2791	2791	1150
Arrive On Green	0.14	0.14	0.79	0.79	0.79	0.79
Sat Flow, veh/h	1657	1430	355	3632	3632	1458
Grp Volume(v), veh/h	166	15	18	492	1001	349
Grp Sat Flow(s),veh/h/ln	1657	1430	355	1770	1770	1458
Q Serve(g_s), s	10.5	1.0	1.7	3.8	9.2	7.3
Cycle Q Clear(g_c), s	10.5	1.0	10.9	3.8	9.2	7.3
Prop In Lane	1.00	1.00	1.00			1.00
Lane Grp Cap(c), veh/h	230	198	316	2791	2791	1150
V/C Ratio(X)	0.72	0.08	0.06	0.18	0.36	0.30
Avail Cap(c_a), veh/h	603	520	316	2791	2791	1150
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	0.64	0.64
Uniform Delay (d), s/veh	45.3	41.2	5.0	2.9	3.4	3.2
Incr Delay (d2), s/veh	4.3	0.2	0.3	0.1	0.2	0.4
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	5.1	0.4	0.2	1.8	4.5	3.0
LnGrp Delay(d),s/veh	49.6	41.4	5.4	3.0	3.7	3.7
LnGrp LOS	D	D	A	A	A	A
Approach Vol, veh/h	181			510	1350	
Approach Delay, s/veh	48.9			3.1	3.7	
Approach LOS	D			A	A	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		
Phs Duration (G+Y+Rc), s		90.7		19.3		90.7		
Change Period (Y+Rc), s		6.0		6.0		6.0		
Max Green Setting (Gmax), s		60.0		38.0		60.0		
Max Q Clear Time (g_c+I1), s		12.9		12.5		11.2		
Green Ext Time (p_c), s		23.9		0.8		24.3		

Intersection Summary	
HCM 2010 Ctrl Delay	7.5
HCM 2010 LOS	A



Movement	EBL	EBT	WBT	WBR	SBL	SBR		
Lane Configurations								
Traffic Volume (veh/h)	303	411	960	260	96	261		
Future Volume (veh/h)	303	411	960	260	96	261		
Number	5	2	6	16	7	14		
Initial Q (Qb), veh	0	0	0	0	0	0		
Ped-Bike Adj(A_pbT)	1.00			1.00	1.00	1.00		
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00		
Adj Sat Flow, veh/h/ln	1707	1845	1810	1535	1757	1699		
Adj Flow Rate, veh/h	329	447	1043	283	104	284		
Adj No. of Lanes	1	2	2	1	1	1		
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92		
Percent Heavy Veh, %	4	3	5	14	1	3		
Cap, veh/h	339	2324	1821	691	415	358		
Arrive On Green	0.09	0.66	0.53	0.53	0.25	0.25		
Sat Flow, veh/h	1625	3597	3529	1304	1674	1444		
Grp Volume(v), veh/h	329	447	1043	283	104	284		
Grp Sat Flow(s),veh/h/ln	1625	1752	1719	1304	1674	1444		
Q Serve(g_s), s	8.0	4.4	18.4	11.7	4.5	16.6		
Cycle Q Clear(g_c), s	8.0	4.4	18.4	11.7	4.5	16.6		
Prop In Lane	1.00			1.00	1.00	1.00		
Lane Grp Cap(c), veh/h	339	2324	1821	691	415	358		
V/C Ratio(X)	0.97	0.19	0.57	0.41	0.25	0.79		
Avail Cap(c_a), veh/h	339	2324	1821	691	707	610		
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00		
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00		
Uniform Delay (d), s/veh	17.6	5.9	14.3	12.7	27.1	31.7		
Incr Delay (d2), s/veh	41.1	0.2	1.3	1.8	0.3	4.0		
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0		
%ile BackOfQ(50%),veh/ln	8.4	2.2	9.0	4.5	2.1	12.8		
LnGrp Delay(d),s/veh	58.7	6.0	15.6	14.5	27.4	35.7		
LnGrp LOS	E	A	B	B	C	D		
Approach Vol, veh/h		776	1326		388			
Approach Delay, s/veh		28.3	15.4		33.5			
Approach LOS		C	B		C			
Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4	5	6		
Phs Duration (G+Y+Rc), s		63.7		26.3	12.0	51.7		
Change Period (Y+Rc), s		6.0		6.0	4.0	6.0		
Max Green Setting (Gmax), s		42.0		36.0	8.0	30.0		
Max Q Clear Time (g_c+I1), s		6.4		18.6	10.0	20.4		
Green Ext Time (p_c), s		19.5		1.8	0.0	7.5		
Intersection Summary								
HCM 2010 Ctrl Delay			22.2					
HCM 2010 LOS			C					

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	106	185	7	17	373	96	8	269	88	93	83	191
Future Volume (veh/h)	106	185	7	17	373	96	8	269	88	93	83	191
Number	1	6	16	5	2	12	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.99	0.99		0.99	0.99		0.99	1.00		0.99
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1740	1634	1000	1775	1863	1636	1775	1493	1000	1757	1549	1000
Adj Flow Rate, veh/h	115	201	8	18	405	104	9	292	96	101	90	208
Adj No. of Lanes	1	1	0	1	1	1	1	1	0	1	1	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	1	1	0	2	7	0	14	14	1	3	3
Cap, veh/h	262	557	22	273	639	472	333	365	120	275	192	443
Arrive On Green	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sat Flow, veh/h	1657	1560	62	1690	1863	1378	1020	1073	353	1674	414	957
Grp Volume(v), veh/h	115	0	209	18	405	104	9	0	388	101	0	298
Grp Sat Flow(s),veh/h/ln	1657	0	1623	1690	1863	1378	1020	0	1425	1674	0	1371
Q Serve(g_s), s	4.0	0.0	11.3	0.1	19.0	6.6	0.8	0.0	23.8	3.2	0.0	19.0
Cycle Q Clear(g_c), s	4.0	0.0	11.3	0.1	19.0	6.6	9.0	0.0	23.8	3.2	0.0	19.0
Prop In Lane	1.00		0.04	1.00		1.00	1.00		0.25	1.00		0.70
Lane Grp Cap(c), veh/h	262	0	579	273	639	472	333	0	485	275	0	635
V/C Ratio(X)	0.44	0.00	0.36	0.07	0.63	0.22	0.03	0.00	0.80	0.37	0.00	0.47
Avail Cap(c_a), veh/h	262	0	579	329	639	472	359	0	521	279	0	674
HCM Platoon Ratio	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Upstream Filter(I)	1.00	0.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	21.9	0.0	33.8	29.4	38.3	32.1	37.5	0.0	40.8	20.5	0.0	33.0
Incr Delay (d2), s/veh	1.2	0.0	1.7	0.1	4.8	1.1	0.0	0.0	8.2	0.8	0.0	0.5
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	1.9	0.0	0.3	0.3	10.7	0.1	0.2	0.0	1.1	0.9	0.0	0.1
LnGrp Delay(d),s/veh	23.1	0.0	35.5	29.5	43.0	33.1	37.6	0.0	49.0	21.3	0.0	33.6
LnGrp LOS	C		D	C	D	C	D		D	C		C
Approach Vol, veh/h		324			527			397			399	
Approach Delay, s/veh		31.1			40.6			48.7			30.5	
Approach LOS		C			D			D			C	
Timer	1	2	3	4	5	6	7	8				
Assigned Phs	1	2	3	4	5	6		8				
Phs Duration (G+Y+Rc), s	9.0	34.0	10.8	33.8	7.8	35.2		44.5				
Change Period (Y+Rc), s	4.0	6.0	6.0	6.0	6.0	6.0		6.0				
Max Green Setting (Gmax), s	5.0	28.0	5.0	30.0	6.0	25.0		41.0				
Max Q Clear Time (g_c+I1), s	6.0	21.0	5.2	25.8	2.1	13.3		21.0				
Green Ext Time (p_c), s	0.0	2.8	0.0	1.9	0.0	3.9		5.5				
Intersection Summary												
HCM 2010 Ctrl Delay			38.2									
HCM 2010 LOS			D									

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	54	737	303	140	617	243	79	395	55	353	817	100
Future Volume (veh/h)	54	737	303	140	617	243	79	395	55	353	817	100
Number	1	6	16	5	2	12	3	8	18	7	4	14
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		1.00	0.95		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1740	1845	1683	1740	1863	1716	1757	1863	1716	1740	1740	1000
Adj Flow Rate, veh/h	60	801	0	152	671	0	86	439	0	392	908	111
Adj No. of Lanes	1	2	1	1	2	1	1	2	1	1	2	0
Peak Hour Factor	0.90	0.92	0.92	0.92	0.92	0.90	0.92	0.90	0.92	0.90	0.90	0.90
Percent Heavy Veh, %	2	3	4	2	2	2	1	2	2	2	2	2
Cap, veh/h	270	1024	418	222	1155	498	236	1225	505	548	1343	164
Arrive On Green	0.05	0.29	0.00	0.07	0.33	0.00	0.05	0.35	0.00	0.17	0.45	0.45
Sat Flow, veh/h	1657	3505	1430	1657	3539	1458	1674	3539	1458	1657	2967	363
Grp Volume(v), veh/h	60	801	0	152	671	0	86	439	0	392	506	513
Grp Sat Flow(s),veh/h/ln	1657	1752	1430	1657	1770	1458	1674	1770	1458	1657	1653	1676
Q Serve(g_s), s	3.1	27.3	0.0	8.2	20.5	0.0	4.4	12.0	0.0	18.9	31.4	31.4
Cycle Q Clear(g_c), s	3.1	27.3	0.0	8.2	20.5	0.0	4.4	12.0	0.0	18.9	31.4	31.4
Prop In Lane	1.00		1.00	1.00		1.00	1.00		1.00	1.00		0.22
Lane Grp Cap(c), veh/h	270	1024	418	222	1155	498	236	1225	505	548	748	759
V/C Ratio(X)	0.22	0.78	0.00	0.68	0.58	0.00	0.36	0.36	0.00	0.72	0.68	0.68
Avail Cap(c_a), veh/h	326	1024	418	222	1155	498	273	1225	505	548	748	759
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	0.00	1.00	1.00	0.00	0.97	0.97	0.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	28.9	42.2	0.0	32.1	36.4	0.0	27.9	31.7	0.0	20.2	28.1	28.1
Incr Delay (d2), s/veh	0.4	5.9	0.0	8.3	2.1	0.0	0.9	0.8	0.0	4.4	4.9	4.8
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	1.4	14.0	0.0	4.2	10.3	0.0	2.1	6.0	0.0	9.2	15.3	15.5
LnGrp Delay(d),s/veh	29.3	48.1	0.0	40.4	38.5	0.0	28.8	32.5	0.0	24.6	32.9	32.8
LnGrp LOS	C	D		D	D		C	C		C	C	C
Approach Vol, veh/h		861			823			525			1411	
Approach Delay, s/veh		46.8			38.9			31.9			30.6	
Approach LOS		D			D			C			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	8.6	48.4	10.1	62.9	13.0	44.0	24.0	49.0
Change Period (Y+Rc), s	4.0	6.0	4.0	6.0	4.0	6.0	4.0	6.0
Max Green Setting (Gmax), s	9.0	38.0	9.0	54.0	9.0	38.0	20.0	43.0
Max Q Clear Time (g_c+I1), s	5.1	22.5	6.4	33.4	10.2	29.3	20.9	14.0
Green Ext Time (p_c), s	0.0	10.0	0.1	11.7	0.0	6.4	0.0	14.2

Intersection Summary	
HCM 2010 Ctrl Delay	36.5
HCM 2010 LOS	D

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	75	41	2	119	10	105	2	768	36	30	949	25
Future Volume (veh/h)	75	41	2	119	10	105	2	768	36	30	949	25
Number	3	8	18	7	4	14	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	0.99		0.99	0.99		0.99	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1690	1650	1000	1740	1574	1000	1000	1603	1000	1000	1708	1733
Adj Flow Rate, veh/h	82	45	2	129	11	114	2	835	39	33	1032	0
Adj No. of Lanes	1	1	0	1	1	0	0	2	0	0	2	1
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	5	0	0	2	3	3	3	3	3	4	4	1
Cap, veh/h	227	349	16	316	26	273	34	2043	95	75	2125	1037
Arrive On Green	0.22	0.22	0.20	0.22	0.22	0.20	0.69	0.70	0.69	0.69	0.70	0.00
Sat Flow, veh/h	1137	1567	70	1253	118	1225	1	2900	135	57	3017	1473
Grp Volume(v), veh/h	82	0	47	129	0	125	462	0	414	554	511	0
Grp Sat Flow(s),veh/h/ln	1137	0	1637	1253	0	1343	1601	0	1435	1597	1476	1473
Q Serve(g_s), s	7.3	0.0	2.5	10.1	0.0	8.9	0.0	0.0	13.2	0.0	17.2	0.0
Cycle Q Clear(g_c), s	16.2	0.0	2.5	12.6	0.0	8.9	13.3	0.0	13.2	15.9	17.2	0.0
Prop In Lane	1.00		0.04	1.00		0.91	0.00		0.09	0.06		1.00
Lane Grp Cap(c), veh/h	227	0	365	316	0	299	1132	0	1011	1131	1040	1037
V/C Ratio(X)	0.36	0.00	0.13	0.41	0.00	0.42	0.41	0.00	0.41	0.49	0.49	0.00
Avail Cap(c_a), veh/h	330	0	513	430	0	421	1132	0	1011	1131	1040	1037
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00	1.00	1.00	0.00
Uniform Delay (d), s/veh	43.6	0.0	34.2	39.3	0.0	37.5	6.8	0.0	6.8	7.2	7.3	0.0
Incr Delay (d2), s/veh	1.0	0.0	0.2	0.8	0.0	0.9	1.1	0.0	1.2	1.5	1.7	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	2.4	0.0	1.2	3.6	0.0	3.4	6.5	0.0	5.5	8.3	7.4	0.0
LnGrp Delay(d),s/veh	44.6	0.0	34.4	40.1	0.0	38.4	7.9	0.0	8.0	8.7	9.0	0.0
LnGrp LOS	D		C	D		D	A		A	A	A	
Approach Vol, veh/h		129			254			876			1065	
Approach Delay, s/veh		40.9			39.3			7.9			8.8	
Approach LOS		D			D			A			A	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4		6		8
Phs Duration (G+Y+Rc), s		81.5		28.5		81.5		28.5
Change Period (Y+Rc), s		6.0		6.0		6.0		6.0
Max Green Setting (Gmax), s		65.5		32.5		65.5		32.5
Max Q Clear Time (g_c+I1), s		15.3		14.6		19.2		18.2
Green Ext Time (p_c), s		26.6		2.2		25.5		2.0

Intersection Summary	
HCM 2010 Ctrl Delay	13.6
HCM 2010 LOS	B

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	133	339	104	102	731	145	191	486	87	129	754	212
Future Volume (veh/h)	133	339	104	102	731	145	191	486	87	129	754	212
Number	1	6	16	5	2	12	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.99	1.00		0.99	1.00		0.98	0.99		0.98
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1740	1699	1000	1775	1628	1000	1675	1690	1000	1740	1698	1000
Adj Flow Rate, veh/h	145	368	113	111	795	158	208	528	95	140	820	230
Adj No. of Lanes	1	2	0	1	2	0	1	2	0	1	2	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	4	4	0	10	10	6	5	5	2	5	5
Cap, veh/h	207	894	271	376	943	187	201	994	178	364	858	240
Arrive On Green	0.07	0.37	0.35	0.07	0.37	0.35	0.17	0.73	0.70	0.07	0.35	0.33
Sat Flow, veh/h	1657	2439	739	1690	2571	511	1595	2712	486	1657	2474	694
Grp Volume(v), veh/h	145	242	239	111	478	475	208	312	311	140	534	516
Grp Sat Flow(s),veh/h/ln	1657	1614	1563	1690	1547	1535	1595	1606	1591	1657	1613	1555
Q Serve(g_s), s	6.7	13.4	13.8	4.9	34.0	34.1	10.4	10.2	10.6	6.7	38.9	38.9
Cycle Q Clear(g_c), s	6.7	13.4	13.8	4.9	34.0	34.1	10.4	10.2	10.6	6.7	38.9	38.9
Prop In Lane	1.00		0.47	1.00		0.33	1.00		0.31	1.00		0.45
Lane Grp Cap(c), veh/h	207	592	573	376	567	563	201	589	584	364	559	539
V/C Ratio(X)	0.70	0.41	0.42	0.30	0.84	0.84	1.04	0.53	0.53	0.38	0.96	0.96
Avail Cap(c_a), veh/h	207	592	573	376	567	563	201	589	584	364	559	539
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00	2.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	28.7	28.3	28.8	22.8	34.8	35.2	27.5	11.5	12.0	24.2	38.3	38.8
Incr Delay (d2), s/veh	18.1	2.1	2.2	2.0	14.2	14.3	73.0	3.4	3.5	3.0	28.6	29.4
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	4.1	6.3	6.3	2.5	16.7	16.6	10.7	4.9	5.0	3.3	21.7	21.0
LnGrp Delay(d),s/veh	46.8	30.4	31.0	24.8	49.1	49.5	100.6	14.9	15.5	27.2	66.9	68.1
LnGrp LOS	D	C	C	C	D	D	F	B	B	C	E	E
Approach Vol, veh/h		626			1064			831			1190	
Approach Delay, s/veh		34.4			46.7			36.5			62.8	
Approach LOS		C			D			D			E	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	12.0	48.0	12.0	48.0	12.0	48.0	14.4	45.6
Change Period (Y+Rc), s	4.0	6.0	4.0	6.0	4.0	6.0	4.0	6.0
Max Green Setting (Gmax), s	8.0	42.0	8.0	42.0	8.0	42.0	10.4	39.6
Max Q Clear Time (g_c+I1), s	12.7	36.1	8.7	12.6	6.9	15.8	12.4	40.9
Green Ext Time (p_c), s	0.0	4.3	0.0	16.0	0.0	12.7	0.0	0.0

Intersection Summary	
HCM 2010 Ctrl Delay	47.5
HCM 2010 LOS	D

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	112	248	200	411	500	12	295	779	123	16	790	133
Future Volume (veh/h)	112	248	200	411	500	12	295	779	123	16	790	133
Number	3	8	18	7	4	14	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	0.99		0.98	0.99		0.99	1.00		0.99	1.00		0.97
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1707	1900	1683	1740	1721	1000	1675	1810	1750	1740	1716	1000
Adj Flow Rate, veh/h	122	270	217	447	543	13	321	847	134	17	859	145
Adj No. of Lanes	1	2	1	1	2	0	1	2	1	1	2	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	4	0	4	2	3	3	6	5	0	2	2	2
Cap, veh/h	344	963	373	496	1184	28	247	1347	574	223	879	148
Arrive On Green	0.07	0.27	0.27	0.17	0.36	0.35	0.12	0.39	0.39	0.08	0.63	0.60
Sat Flow, veh/h	1625	3610	1398	1657	3264	78	1595	3438	1466	1657	2777	469
Grp Volume(v), veh/h	122	270	217	447	272	284	321	847	134	17	504	500
Grp Sat Flow(s),veh/h/ln	1625	1805	1398	1657	1635	1707	1595	1719	1466	1657	1630	1615
Q Serve(g_s), s	6.6	7.1	16.2	20.0	15.2	15.3	14.0	23.9	7.3	0.8	35.7	35.8
Cycle Q Clear(g_c), s	6.6	7.1	16.2	20.0	15.2	15.3	14.0	23.9	7.3	0.8	35.7	35.8
Prop In Lane	1.00		1.00	1.00		0.05	1.00		1.00	1.00		0.29
Lane Grp Cap(c), veh/h	344	963	373	496	593	619	247	1347	574	223	516	511
V/C Ratio(X)	0.35	0.28	0.58	0.90	0.46	0.46	1.30	0.63	0.23	0.08	0.98	0.98
Avail Cap(c_a), veh/h	351	963	373	496	593	619	247	1347	574	250	516	511
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00	2.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	30.0	34.9	38.2	30.0	29.2	29.3	34.5	29.5	24.4	26.0	21.6	22.2
Incr Delay (d2), s/veh	0.6	0.7	6.5	19.5	2.5	2.4	161.1	2.2	1.0	0.1	34.3	34.5
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	3.0	3.7	6.9	8.4	7.3	7.6	19.2	11.7	3.1	0.4	20.6	20.5
LnGrp Delay(d),s/veh	30.6	35.6	44.7	49.4	31.8	31.7	195.6	31.7	25.4	26.2	55.9	56.7
LnGrp LOS	C	D	D	D	C	C	F	C	C	C	E	E
Approach Vol, veh/h		609			1003			1302			1021	
Approach Delay, s/veh		37.8			39.6			71.5			55.8	
Approach LOS		D			D			E			E	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	9.0	51.0	12.5	47.5	18.0	42.0	24.0	36.0
Change Period (Y+Rc), s	4.0	6.0	4.0	6.0	4.0	6.0	4.0	6.0
Max Green Setting (Gmax), s	7.0	43.0	9.0	41.0	14.0	36.0	20.0	30.0
Max Q Clear Time (g_c+I1), s	12.8	25.9	8.6	17.3	16.0	37.8	22.0	18.2
Green Ext Time (p_c), s	0.0	12.9	0.0	7.9	0.0	0.0	0.0	5.5

Intersection Summary	
HCM 2010 Ctrl Delay	54.1
HCM 2010 LOS	D

Intersection	
Intersection Delay, s/veh	46.0
Intersection LOS	F

Approach	EB	WB	NB	SB
Entry Lanes	2	2	2	2
Conflicting Circle Lanes	2	2	2	2
Adj Approach Flow, veh/h	954	977	1486	1154
Demand Flow Rate, veh/h	973	1017	1516	1171
Vehicles Circulating, veh/h	1214	1601	780	1250
Vehicles Exiting, veh/h	1033	528	1407	1368
Follow-Up Headway, s	3.186	3.186	3.186	3.186
Ped Vol Crossing Leg, #/h	0	1	0	12
Ped Cap Adj	1.000	1.000	1.000	1.000
Approach Delay, s/veh	108.3	242.0	152.9	86.9
Approach LOS	F	F	F	F

Lane	Left	Right	Left	Right	Left	Right	Bypass	Left	Right	Bypass
Designated Moves	LT	R	LT	TR	L	TR	R	LT	TR	R
Assumed Moves	LT	R	LT	TR	L	TR	R	LT	TR	R
RT Channelized							Yield			Yield
Lane Util	0.584	0.416	0.470	0.530	0.292	0.708		0.470	0.530	
Critical Headway, s	4.293	4.113	4.293	4.113	4.293	4.113		4.293	4.113	
Entry Flow, veh/h	568	405	478	539	394	955	167	469	528	174
Cap Entry Lane, veh/h	455	483	340	368	629	655	666	442	471	548
Entry HV Adj Factor	0.980	0.980	0.960	0.961	0.980	0.980	0.980	0.984	0.985	0.990
Flow Entry, veh/h	557	397	459	518	386	936	164	461	520	172
Cap Entry, veh/h	446	474	327	354	617	642	653	435	464	543
V/C Ratio	1.249	0.838	1.406	1.463	0.626	1.459	0.251	1.060	1.121	0.317
Control Delay, s/veh	156.9	40.2	231.0	251.8	18.2	233.7	8.6	91.0	108.2	11.3
LOS	F	E	F	F	C	F	A	F	F	B
95th %tile Queue, veh	23	8	24	28	4	45	1	15	18	1

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	55	464	112	327	965	95	217	417	115	63	554	111
Future Volume (veh/h)	55	464	112	327	965	95	217	417	115	63	554	111
Number	1	6	16	5	2	12	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.98	0.99		0.98	0.99		0.98	0.99		0.98
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1740	1863	1733	1690	1634	1000	1659	1731	1000	1740	1881	1750
Adj Flow Rate, veh/h	60	504	122	355	1049	103	236	453	125	68	602	121
Adj No. of Lanes	1	2	1	1	2	0	1	2	0	1	2	1
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	2	1	5	7	7	7	3	3	2	1	0
Cap, veh/h	174	1182	482	461	1297	127	314	846	231	262	882	359
Arrive On Green	0.04	0.33	0.33	0.16	0.45	0.44	0.13	0.33	0.32	0.04	0.25	0.25
Sat Flow, veh/h	1657	3539	1442	1610	2852	280	1580	2542	695	1657	3574	1453
Grp Volume(v), veh/h	60	504	122	355	571	581	236	292	286	68	602	121
Grp Sat Flow(s),veh/h/ln	1657	1770	1442	1610	1553	1580	1580	1644	1593	1657	1787	1453
Q Serve(g_s), s	2.9	13.3	7.4	17.3	38.0	38.2	13.2	17.3	17.7	3.7	18.3	8.2
Cycle Q Clear(g_c), s	2.9	13.3	7.4	17.3	38.0	38.2	13.2	17.3	17.7	3.7	18.3	8.2
Prop In Lane	1.00		1.00	1.00		0.18	1.00		0.44	1.00		1.00
Lane Grp Cap(c), veh/h	174	1182	482	461	706	718	314	547	530	262	882	359
V/C Ratio(X)	0.34	0.43	0.25	0.77	0.81	0.81	0.75	0.53	0.54	0.26	0.68	0.34
Avail Cap(c_a), veh/h	225	1182	482	461	706	718	358	586	568	301	953	388
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	28.7	31.0	29.1	21.9	28.2	28.4	30.1	32.5	32.9	33.3	40.9	37.1
Incr Delay (d2), s/veh	1.2	1.1	1.3	7.8	9.7	9.6	7.6	0.8	0.9	0.5	1.8	0.6
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	1.4	6.7	3.1	8.6	18.1	18.6	6.4	8.0	7.9	1.7	9.3	3.4
LnGrp Delay(d),s/veh	29.9	32.2	30.3	29.7	37.9	38.0	37.7	33.3	33.8	33.8	42.8	37.7
LnGrp LOS	C	C	C	C	D	D	D	C	C	C	D	D
Approach Vol, veh/h		686			1507			814			791	
Approach Delay, s/veh		31.6			36.0			34.8			41.2	
Approach LOS		C			D			C			D	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	8.3	58.6	9.2	43.9	22.8	44.1	19.5	33.6
Change Period (Y+Rc), s	4.0	6.0	4.0	6.0	4.0	6.0	4.0	6.0
Max Green Setting (Gmax), s	4.3	43.2	8.0	40.8	18.8	32.4	18.8	30.0
Max Q Clear Time (g_c+I1), s	4.9	40.2	5.7	19.7	19.3	15.3	15.2	20.3
Green Ext Time (p_c), s	0.0	2.6	0.0	10.2	0.0	11.9	0.3	6.1

Intersection Summary	
HCM 2010 Ctrl Delay	36.0
HCM 2010 LOS	D

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	103	280	77	368	686	277	153	293	129	131	604	240
Future Volume (veh/h)	103	280	77	368	686	277	153	293	129	131	604	240
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.99	0.99		0.99	1.00		1.00	0.99		0.98
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1757	1863	1651	1675	1672	1000	1690	1863	1699	1740	1845	1651
Adj Flow Rate, veh/h	103	280	77	368	686	277	153	293	0	131	604	240
Adj No. of Lanes	1	2	1	1	2	0	1	2	1	1	2	1
Peak Hour Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Percent Heavy Veh, %	1	2	6	6	7	7	5	2	3	2	3	6
Cap, veh/h	215	1102	432	504	875	353	292	1218	497	443	1169	459
Arrive On Green	0.06	0.31	0.31	0.14	0.40	0.38	0.08	0.34	0.00	0.07	0.33	0.33
Sat Flow, veh/h	1674	3539	1388	1595	2200	889	1610	3539	1444	1657	3505	1376
Grp Volume(v), veh/h	103	280	77	368	495	468	153	293	0	131	604	240
Grp Sat Flow(s),veh/h/ln	1674	1770	1388	1595	1589	1500	1610	1770	1444	1657	1752	1376
Q Serve(g_s), s	5.2	7.2	4.9	17.6	33.3	33.4	7.7	7.2	0.0	6.4	16.9	17.2
Cycle Q Clear(g_c), s	5.2	7.2	4.9	17.6	33.3	33.4	7.7	7.2	0.0	6.4	16.9	17.2
Prop In Lane	1.00		1.00	1.00		0.59	1.00		1.00	1.00		1.00
Lane Grp Cap(c), veh/h	215	1102	432	504	632	597	292	1218	497	443	1169	459
V/C Ratio(X)	0.48	0.25	0.18	0.73	0.78	0.78	0.52	0.24	0.00	0.30	0.52	0.52
Avail Cap(c_a), veh/h	277	1102	432	504	632	597	301	1218	497	470	1169	459
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	29.9	31.4	30.6	25.1	32.1	32.7	26.1	28.6	0.0	25.1	32.7	32.8
Incr Delay (d2), s/veh	1.7	0.6	0.9	5.3	9.4	9.9	1.5	0.5	0.0	0.4	1.6	4.2
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	2.5	3.6	2.0	3.6	16.2	15.5	3.5	3.6	0.0	3.0	8.5	7.0
LnGrp Delay(d),s/veh	31.5	32.0	31.5	30.5	41.6	42.6	27.7	29.1	0.0	25.5	34.4	37.0
LnGrp LOS	C	C	C	C	D	D	C	C		C	C	D
Approach Vol, veh/h		460			1331			446			975	
Approach Delay, s/veh		31.8			38.9			28.6			33.8	
Approach LOS		C			D			C			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	12.4	46.0	21.6	42.0	13.7	44.7	11.1	52.5
Change Period (Y+Rc), s	4.0	6.0	4.0	6.0	4.0	6.0	4.0	6.0
Max Green Setting (Gmax), s	10.4	38.4	17.6	36.0	10.4	38.4	11.6	42.0
Max Q Clear Time (g_c+I1), s	19.4	9.2	19.6	9.2	9.7	19.2	7.2	35.4
Green Ext Time (p_c), s	0.1	9.6	0.0	12.2	0.0	8.1	0.1	4.6

Intersection Summary	
HCM 2010 Ctrl Delay	34.9
HCM 2010 LOS	C

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	112	93	86	50	202	77	182	692	65	54	1114	199
Future Volume (veh/h)	112	93	86	50	202	77	182	692	65	54	1114	199
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.99	0.99		0.99	1.00		0.99	1.00		0.99
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1740	1845	1733	1723	1531	1000	1740	1718	1000	1740	1713	1000
Adj Flow Rate, veh/h	124	103	96	56	224	86	202	769	72	60	1238	221
Adj No. of Lanes	1	1	1	1	1	0	1	2	0	1	2	0
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	2	3	1	3	10	10	2	3	3	2	3	3
Cap, veh/h	276	681	536	438	388	149	205	1369	128	300	1164	206
Arrive On Green	0.37	0.37	0.37	0.37	0.37	0.35	0.08	0.45	0.43	0.04	0.42	0.40
Sat Flow, veh/h	991	1845	1451	1079	1051	404	1657	3013	282	1657	2758	488
Grp Volume(v), veh/h	124	103	96	56	0	310	202	416	425	60	726	733
Grp Sat Flow(s),veh/h/ln	991	1845	1451	1079	0	1455	1657	1632	1664	1657	1628	1619
Q Serve(g_s), s	10.3	3.4	4.0	3.3	0.0	15.4	6.6	16.8	16.9	1.9	38.0	38.0
Cycle Q Clear(g_c), s	25.8	3.4	4.0	6.6	0.0	15.4	6.6	16.8	16.9	1.9	38.0	38.0
Prop In Lane	1.00		1.00	1.00		0.28	1.00		0.17	1.00		0.30
Lane Grp Cap(c), veh/h	276	681	536	438	0	537	205	741	756	300	687	683
V/C Ratio(X)	0.45	0.15	0.18	0.13	0.00	0.58	0.98	0.56	0.56	0.20	1.06	1.07
Avail Cap(c_a), veh/h	341	803	632	510	0	634	205	741	756	353	687	683
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	33.1	19.0	19.2	21.2	0.0	23.0	21.9	18.0	18.1	15.7	26.0	26.3
Incr Delay (d2), s/veh	1.1	0.1	0.2	0.1	0.0	1.0	58.1	3.1	3.0	0.3	50.7	55.6
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	2.9	1.7	1.6	1.0	0.0	6.3	8.3	8.1	8.3	0.9	26.6	27.4
LnGrp Delay(d),s/veh	34.3	19.1	19.3	21.3	0.0	24.0	80.0	21.1	21.1	16.0	76.7	81.9
LnGrp LOS	C	B	B	C		C	E	C	C	B	F	F
Approach Vol, veh/h		323			366			1043			1519	
Approach Delay, s/veh		25.0			23.6			32.5			76.8	
Approach LOS		C			C			C			E	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4	5	6		8
Phs Duration (G+Y+Rc), s	7.9	44.9		37.2	10.8	42.0		37.2
Change Period (Y+Rc), s	4.0	6.0		6.0	4.0	6.0		6.0
Max Green Setting (Gmax), s	6.8	30.0		37.2	6.8	30.0		37.2
Max Q Clear Time (g_c+I1), s	13.9	18.9		27.8	8.6	40.0		17.4
Green Ext Time (p_c), s	0.0	9.8		3.2	0.0	0.0		4.7

Intersection Summary	
HCM 2010 Ctrl Delay	51.4
HCM 2010 LOS	D

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	117	57	126	102	102	28	210	261	78	38	657	253
Future Volume (veh/h)	117	57	126	102	102	28	210	261	78	38	657	253
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	0.99		0.99	1.00		0.99	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1757	1617	1000	1775	1900	1750	1675	1630	1000	1659	1792	1683
Adj Flow Rate, veh/h	127	62	137	111	111	30	228	284	85	41	714	275
Adj No. of Lanes	1	1	0	1	1	1	1	1	0	1	1	1
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	1	0	0	0	0	0	6	1	1	7	6	4
Cap, veh/h	350	123	271	258	523	404	302	762	228	524	881	701
Arrive On Green	0.28	0.28	0.25	0.28	0.28	0.28	0.10	0.63	0.61	0.49	0.49	0.49
Sat Flow, veh/h	1161	446	986	1118	1900	1469	1595	1205	361	897	1792	1426
Grp Volume(v), veh/h	127	0	199	111	111	30	228	0	369	41	714	275
Grp Sat Flow(s),veh/h/ln	1161	0	1433	1118	1900	1469	1595	0	1565	897	1792	1426
Q Serve(g_s), s	8.2	0.0	10.3	8.1	3.9	1.3	6.0	0.0	10.0	2.1	29.3	10.6
Cycle Q Clear(g_c), s	12.1	0.0	10.3	18.4	3.9	1.3	6.0	0.0	10.0	2.1	29.3	10.6
Prop In Lane	1.00		0.69	1.00		1.00	1.00		0.23	1.00		1.00
Lane Grp Cap(c), veh/h	350	0	394	258	523	404	302	0	991	524	881	701
V/C Ratio(X)	0.36	0.00	0.50	0.43	0.21	0.07	0.75	0.00	0.37	0.08	0.81	0.39
Avail Cap(c_a), veh/h	391	0	445	298	590	456	370	0	991	524	881	701
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	28.9	0.0	27.1	34.3	24.3	23.3	17.5	0.0	7.8	11.8	18.7	13.9
Incr Delay (d2), s/veh	0.6	0.0	1.0	1.1	0.2	0.1	6.9	0.0	1.1	0.3	8.0	1.6
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	2.7	0.0	4.2	2.6	2.1	0.5	3.2	0.0	4.5	0.6	16.2	4.4
LnGrp Delay(d),s/veh	29.5	0.0	28.1	35.4	24.5	23.4	24.3	0.0	8.9	12.1	26.7	15.6
LnGrp LOS	C		C	D	C	C	C		A	B	C	B
Approach Vol, veh/h		326			252			597			1030	
Approach Delay, s/veh		28.7			29.2			14.8			23.1	
Approach LOS		C			C			B			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2		4	5	6		8
Phs Duration (G+Y+Rc), s		59.0		27.9	12.3	46.7		27.9
Change Period (Y+Rc), s		6.0		6.0	4.0	6.0		6.0
Max Green Setting (Gmax), s		53.0		25.0	12.0	37.0		25.0
Max Q Clear Time (g_c+I1), s		12.0		14.1	8.0	31.3		20.4
Green Ext Time (p_c), s		14.4		2.8	0.3	4.1		1.5

Intersection Summary	
HCM 2010 Ctrl Delay	22.4
HCM 2010 LOS	C

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	16	120	127	143	157	87	138	283	111	52	278	25
Future Volume (veh/h)	16	120	127	143	157	87	138	283	111	52	278	25
Number	3	8	18	7	4	14	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	0.83		0.69	0.79		0.68	0.97		0.92	0.96		0.91
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1659	1845	1683	1599	1567	1000	1723	1681	1750	1707	1497	1000
Adj Flow Rate, veh/h	16	120	127	143	157	87	138	283	111	52	278	25
Adj No. of Lanes	1	1	1	1	1	0	1	1	1	1	1	0
Peak Hour Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Percent Heavy Veh, %	7	3	4	11	6	6	3	13	0	4	10	10
Cap, veh/h	312	779	418	374	337	187	378	680	554	372	499	45
Arrive On Green	0.42	0.42	0.42	0.42	0.42	0.40	0.07	0.40	0.40	0.04	0.37	0.35
Sat Flow, veh/h	832	1845	991	769	798	442	1641	1681	1372	1625	1341	121
Grp Volume(v), veh/h	16	120	127	143	0	244	138	283	111	52	0	303
Grp Sat Flow(s),veh/h/ln	832	1845	991	769	0	1240	1641	1681	1372	1625	0	1461
Q Serve(g_s), s	1.3	3.6	7.6	12.7	0.0	12.9	4.7	10.9	4.7	1.8	0.0	14.8
Cycle Q Clear(g_c), s	14.1	3.6	7.6	16.3	0.0	12.9	4.7	10.9	4.7	1.8	0.0	14.8
Prop In Lane	1.00		1.00	1.00		0.36	1.00		1.00	1.00		0.08
Lane Grp Cap(c), veh/h	312	779	418	374	0	523	378	680	554	372	0	544
V/C Ratio(X)	0.05	0.15	0.30	0.38	0.00	0.47	0.37	0.42	0.20	0.14	0.00	0.56
Avail Cap(c_a), veh/h	312	779	419	374	0	524	404	680	554	397	0	544
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	23.8	16.1	17.2	21.1	0.0	19.0	17.4	19.2	17.4	17.7	0.0	22.5
Incr Delay (d2), s/veh	0.1	0.1	0.4	0.6	0.0	0.6	0.6	1.9	0.8	0.2	0.0	4.1
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.3	1.9	2.1	2.8	0.0	4.5	2.2	5.4	1.9	0.8	0.0	6.6
LnGrp Delay(d),s/veh	23.9	16.2	17.6	21.8	0.0	19.7	18.0	21.1	18.2	17.8	0.0	26.5
LnGrp LOS	C	B	B	C		B	B	C	B	B		C
Approach Vol, veh/h		263			387			532			355	
Approach Delay, s/veh		17.4			20.4			19.7			25.3	
Approach LOS		B			C			B			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4	5	6		8
Phs Duration (G+Y+Rc), s	7.6	40.4		42.0	10.5	37.5		42.0
Change Period (Y+Rc), s	4.0	6.0		6.0	4.0	6.0		6.0
Max Green Setting (Gmax), s	5.6	33.0		36.0	8.0	30.0		36.0
Max Q Clear Time (g_c+I1), s	3.8	12.9		18.3	6.7	16.8		16.1
Green Ext Time (p_c), s	0.0	4.8		4.9	0.1	4.0		5.2

Intersection Summary	
HCM 2010 Ctrl Delay	20.8
HCM 2010 LOS	C

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	256	262	289	19	194	25	231	419	13	40	527	110
Future Volume (veh/h)	256	262	289	19	194	25	231	419	13	40	527	110
Number	3	8	18	7	4	14	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.99	1.00		0.99	1.00		1.00	1.00		0.99
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1675	1810	1699	1690	1621	1000	1659	1614	1000	1644	1577	1000
Adj Flow Rate, veh/h	256	262	289	19	194	25	231	419	13	40	527	110
Adj No. of Lanes	1	1	1	1	1	0	1	1	0	1	1	0
Peak Hour Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Percent Heavy Veh, %	6	5	3	5	2	2	7	2	2	8	5	5
Cap, veh/h	310	597	474	239	323	42	258	919	28	440	560	117
Arrive On Green	0.08	0.33	0.33	0.23	0.23	0.22	0.11	0.59	0.58	0.44	0.44	0.44
Sat Flow, veh/h	1595	1810	1435	771	1406	181	1580	1557	48	838	1264	264
Grp Volume(v), veh/h	256	262	289	19	0	219	231	0	432	40	0	637
Grp Sat Flow(s),veh/h/ln	1595	1810	1435	771	0	1587	1580	0	1605	838	0	1528
Q Serve(g_s), s	8.0	11.3	16.9	2.0	0.0	12.3	8.7	0.0	15.1	2.8	0.0	39.9
Cycle Q Clear(g_c), s	8.0	11.3	16.9	3.3	0.0	12.3	8.7	0.0	15.1	3.2	0.0	39.9
Prop In Lane	1.00		1.00	1.00		0.11	1.00		0.03	1.00		0.17
Lane Grp Cap(c), veh/h	310	597	474	239	0	365	258	0	947	440	0	676
V/C Ratio(X)	0.83	0.44	0.61	0.08	0.00	0.60	0.89	0.00	0.46	0.09	0.00	0.94
Avail Cap(c_a), veh/h	310	597	474	239	0	365	263	0	947	440	0	676
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	33.2	26.2	28.1	31.5	0.0	34.4	24.6	0.0	11.5	16.5	0.0	26.6
Incr Delay (d2), s/veh	16.4	2.3	5.8	0.6	0.0	7.1	29.4	0.0	1.6	0.4	0.0	23.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	5.0	6.1	7.4	0.5	0.0	6.1	8.3	0.0	7.0	0.7	0.0	20.9
LnGrp Delay(d),s/veh	49.7	28.6	33.9	32.1	0.0	41.6	54.0	0.0	13.1	16.9	0.0	49.6
LnGrp LOS	D	C	C	C		D	D		B	B		D
Approach Vol, veh/h		807			238			663			677	
Approach Delay, s/veh		37.2			40.8			27.4			47.7	
Approach LOS		D			D			C			D	

Timer	1	2	3	4	5	6	7	8
Assigned Phs		2	3	4	5	6		8
Phs Duration (G+Y+Rc), s		63.0	10.0	27.0	14.7	48.3		37.0
Change Period (Y+Rc), s		6.0	4.0	6.0	4.0	6.0		6.0
Max Green Setting (Gmax), s		57.0	6.0	21.0	11.0	42.0		31.0
Max Q Clear Time (g_c+I1), s		17.1	10.0	14.3	10.7	41.9		18.9
Green Ext Time (p_c), s		15.9	0.0	3.6	0.1	0.1		5.6

Intersection Summary	
HCM 2010 Ctrl Delay	37.8
HCM 2010 LOS	D

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	357	920	338	96	600	53	281	350	97	169	440	427
Future Volume (veh/h)	357	920	338	96	600	53	281	350	97	169	440	427
Number	3	8	18	7	4	14	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		0.98	0.99		0.98
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1690	1670	1000	1707	1845	1620	1740	1707	1000	1775	1827	1716
Adj Flow Rate, veh/h	397	1022	376	107	667	59	312	389	108	188	489	474
Adj No. of Lanes	1	2	0	1	2	1	1	2	0	1	1	1
Peak Hour Factor	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Percent Heavy Veh, %	5	6	6	4	3	8	2	4	4	0	4	2
Cap, veh/h	418	881	320	152	835	327	282	894	245	359	542	700
Arrive On Green	0.21	0.39	0.37	0.06	0.24	0.24	0.13	0.36	0.35	0.07	0.30	0.28
Sat Flow, veh/h	1610	2279	829	1625	3505	1372	1657	2507	687	1690	1827	1430
Grp Volume(v), veh/h	397	708	690	107	667	59	312	250	247	188	489	474
Grp Sat Flow(s),veh/h/ln	1610	1587	1521	1625	1752	1372	1657	1621	1573	1690	1827	1430
Q Serve(g_s), s	22.5	46.4	46.4	6.1	21.5	4.1	15.2	14.1	14.4	8.0	30.8	30.6
Cycle Q Clear(g_c), s	22.5	46.4	46.4	6.1	21.5	4.1	15.2	14.1	14.4	8.0	30.8	30.6
Prop In Lane	1.00		0.54	1.00		1.00	1.00		0.44	1.00		1.00
Lane Grp Cap(c), veh/h	418	614	588	152	835	327	282	578	561	359	542	700
V/C Ratio(X)	0.95	1.15	1.17	0.70	0.80	0.18	1.10	0.43	0.44	0.52	0.90	0.68
Avail Cap(c_a), veh/h	421	614	588	152	835	327	282	578	561	359	542	700
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	29.4	36.8	37.3	36.4	43.0	36.4	32.6	29.4	29.6	30.4	40.5	23.8
Incr Delay (d2), s/veh	31.1	86.6	95.0	13.6	7.9	1.2	84.6	2.3	2.5	1.4	20.8	5.2
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	16.5	35.0	35.0	3.3	11.3	1.7	16.0	6.7	6.7	1.6	18.6	13.1
LnGrp Delay(d),s/veh	60.5	123.4	132.4	50.0	50.9	37.6	117.3	31.7	32.1	31.7	61.3	29.0
LnGrp LOS	E	F	F	D	D	D	F	C	C	C	E	C
Approach Vol, veh/h		1795			833			809			1151	
Approach Delay, s/veh		112.9			49.8			64.8			43.2	
Approach LOS		F			D			E			D	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	12.0	46.8	28.6	32.6	19.2	39.6	10.8	50.4
Change Period (Y+Rc), s	4.0	6.0	4.0	6.0	4.0	6.0	4.0	6.0
Max Green Setting (Gmax), s	8.0	40.8	24.8	26.4	15.2	33.6	6.8	44.4
Max Q Clear Time (g_c+I1), s	10.0	16.4	24.5	23.5	17.2	32.8	8.1	48.4
Green Ext Time (p_c), s	0.0	15.6	0.1	2.8	0.0	0.7	0.0	0.0

Intersection Summary	
HCM 2010 Ctrl Delay	75.5
HCM 2010 LOS	E

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	116	732	218	118	448	49	170	124	116	113	305	285
Future Volume (veh/h)	116	732	218	118	448	49	170	124	116	113	305	285
Number	1	6	16	5	2	12	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.97	1.00		0.98	1.00		0.98	0.98		0.98
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1757	1776	1683	1775	1681	1000	1740	1715	1000	1707	1616	1000
Adj Flow Rate, veh/h	126	796	237	128	487	53	185	135	126	123	332	310
Adj No. of Lanes	1	2	1	1	2	0	1	2	0	1	2	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	1	7	4	0	6	6	2	3	3	4	5	5
Cap, veh/h	393	1397	576	261	1203	130	261	686	586	348	431	377
Arrive On Green	0.02	0.14	0.14	0.06	0.41	0.40	0.10	0.41	0.40	0.28	0.28	0.28
Sat Flow, veh/h	1674	3374	1391	1690	2901	314	1657	1655	1413	1005	1535	1343
Grp Volume(v), veh/h	126	796	237	128	267	273	185	133	128	123	332	310
Grp Sat Flow(s),veh/h/ln	1674	1687	1391	1690	1597	1619	1657	1629	1439	1005	1535	1343
Q Serve(g_s), s	4.8	24.3	17.2	4.9	12.9	13.1	8.6	5.7	6.5	11.0	21.8	23.7
Cycle Q Clear(g_c), s	4.8	24.3	17.2	4.9	12.9	13.1	8.6	5.7	6.5	11.0	21.8	23.7
Prop In Lane	1.00		1.00	1.00		0.19	1.00		0.98	1.00		1.00
Lane Grp Cap(c), veh/h	393	1397	576	261	662	671	261	676	597	348	431	377
V/C Ratio(X)	0.32	0.57	0.41	0.49	0.40	0.41	0.71	0.20	0.22	0.35	0.77	0.82
Avail Cap(c_a), veh/h	442	1397	576	310	662	671	296	741	654	367	461	403
HCM Platoon Ratio	0.33	0.33	0.33	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	19.2	38.3	35.2	21.0	22.6	22.8	27.8	20.5	21.4	32.4	36.3	37.0
Incr Delay (d2), s/veh	0.5	1.7	2.2	1.4	1.8	1.8	6.6	0.1	0.2	0.6	7.3	12.2
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	2.3	11.7	7.0	2.3	6.1	6.2	4.4	2.6	2.6	3.1	10.1	10.1
LnGrp Delay(d),s/veh	19.7	40.0	37.4	22.5	24.5	24.6	34.4	20.7	21.6	33.0	43.6	49.2
LnGrp LOS	B	D	D	C	C	C	C	C	C	C	D	D
Approach Vol, veh/h		1159			668			446			765	
Approach Delay, s/veh		37.3			24.1			26.6			44.2	
Approach LOS		D			C			C			D	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4	5	6	7	8
Phs Duration (G+Y+Rc), s	10.8	49.6		49.6	10.9	49.5	14.7	34.9
Change Period (Y+Rc), s	4.0	6.0		6.0	4.0	6.0	4.0	6.0
Max Green Setting (Gmax), s	10.8	36.0		48.0	10.0	36.0	13.0	31.0
Max Q Clear Time (g_c+I1), s	11.8	15.1		8.5	6.9	26.3	10.6	25.7
Green Ext Time (p_c), s	0.1	11.9		10.0	0.1	6.8	0.2	3.1

Intersection Summary	
HCM 2010 Ctrl Delay	34.6
HCM 2010 LOS	C

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	159	497	103	227	444	67	147	370	163	103	432	168
Future Volume (veh/h)	159	497	103	227	444	67	147	370	163	103	432	168
Number	3	8	18	7	4	14	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	0.99		0.99	1.00		0.99	0.99		0.98	0.99		0.98
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1740	1692	1000	1675	1693	1000	1628	1827	1651	1707	1776	1606
Adj Flow Rate, veh/h	173	540	112	247	483	73	160	402	177	112	470	183
Adj No. of Lanes	1	2	0	1	2	0	1	2	1	1	2	1
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	2	3	3	6	5	5	9	4	6	4	7	9
Cap, veh/h	387	900	186	364	1046	157	321	1143	453	324	1028	407
Arrive On Green	0.09	0.34	0.34	0.12	0.37	0.37	0.03	0.11	0.11	0.06	0.30	0.30
Sat Flow, veh/h	1657	2647	547	1595	2799	421	1551	3471	1375	1625	3374	1335
Grp Volume(v), veh/h	173	327	325	247	276	280	160	402	177	112	470	183
Grp Sat Flow(s),veh/h/ln	1657	1608	1587	1595	1608	1612	1551	1736	1375	1625	1687	1335
Q Serve(g_s), s	7.6	18.5	18.7	10.9	14.3	14.5	7.7	11.8	13.2	5.3	12.4	12.1
Cycle Q Clear(g_c), s	7.6	18.5	18.7	10.9	14.3	14.5	7.7	11.8	13.2	5.3	12.4	12.1
Prop In Lane	1.00		0.34	1.00		0.26	1.00		1.00	1.00		1.00
Lane Grp Cap(c), veh/h	387	546	539	364	601	602	321	1143	453	324	1028	407
V/C Ratio(X)	0.45	0.60	0.60	0.68	0.46	0.46	0.50	0.35	0.39	0.35	0.46	0.45
Avail Cap(c_a), veh/h	397	546	539	416	601	602	359	1143	453	355	1028	407
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	0.33	0.33	0.33	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	22.1	30.1	30.1	22.0	26.1	26.1	26.0	38.1	38.8	25.3	30.9	30.8
Incr Delay (d2), s/veh	0.8	4.8	4.9	3.7	2.5	2.6	1.2	0.9	2.5	0.6	1.5	3.6
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	3.5	9.0	9.0	5.1	6.7	6.9	3.4	5.8	5.3	2.4	6.0	4.9
LnGrp Delay(d),s/veh	23.0	34.9	35.1	25.8	28.6	28.7	27.2	39.0	41.3	25.9	32.4	34.4
LnGrp LOS	C	C	D	C	C	C	C	D	D	C	C	C
Approach Vol, veh/h		825			803			739			765	
Approach Delay, s/veh		32.5			27.7			37.0			31.9	
Approach LOS		C			C			D			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	11.1	40.2	13.6	45.1	13.8	37.5	17.3	41.4
Change Period (Y+Rc), s	4.0	6.0	4.0	6.0	4.0	6.0	4.0	6.0
Max Green Setting (Gmax), s	9.2	31.4	10.3	39.1	12.5	28.1	16.9	32.5
Max Q Clear Time (g_c+I1), s	11.3	15.2	9.6	16.5	9.7	14.4	12.9	20.7
Green Ext Time (p_c), s	0.1	7.8	0.0	9.4	0.1	7.0	0.4	6.4

Intersection Summary	
HCM 2010 Ctrl Delay	32.2
HCM 2010 LOS	C

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	108	798	193	185	567	190	169	772	185	223	919	70
Future Volume (veh/h)	108	798	193	185	567	190	169	772	185	223	919	70
Number	3	8	18	7	4	14	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	0.97		0.93	1.00		1.00	1.00		0.94	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1644	1759	1667	1740	1703	1000	1599	1845	1606	1690	1734	1000
Adj Flow Rate, veh/h	117	867	210	201	616	0	184	839	201	242	999	0
Adj No. of Lanes	1	2	1	1	2	0	1	2	1	1	2	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	8	8	5	2	4	4	11	3	9	5	2	2
Cap, veh/h	433	1276	633	307	1322	0	209	1094	401	259	1028	0
Arrive On Green	0.03	0.13	0.13	0.21	0.82	0.00	0.09	0.31	0.31	0.03	0.10	0.00
Sat Flow, veh/h	1565	3343	1320	1657	3320	0	1523	3505	1285	1610	3382	0
Grp Volume(v), veh/h	117	867	210	201	616	0	184	839	201	242	999	0
Grp Sat Flow(s),veh/h/ln	1565	1671	1320	1657	1617	0	1523	1752	1285	1610	1647	0
Q Serve(g_s), s	4.8	27.3	13.8	7.7	6.2	0.0	9.0	23.8	14.0	10.0	33.2	0.0
Cycle Q Clear(g_c), s	4.8	27.3	13.8	7.7	6.2	0.0	9.0	23.8	14.0	10.0	33.2	0.0
Prop In Lane	1.00		1.00	1.00		0.00	1.00		1.00	1.00		0.00
Lane Grp Cap(c), veh/h	433	1276	633	307	1322	0	209	1094	401	259	1028	0
V/C Ratio(X)	0.27	0.68	0.33	0.66	0.47	0.00	0.88	0.77	0.50	0.94	0.97	0.00
Avail Cap(c_a), veh/h	480	1276	633	312	1322	0	209	1094	401	259	1028	0
HCM Platoon Ratio	0.33	0.33	0.33	2.00	2.00	2.00	1.00	1.00	1.00	0.33	0.33	0.33
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	0.00
Uniform Delay (d), s/veh	18.3	41.6	26.8	18.9	6.5	0.0	27.6	34.2	30.9	31.2	48.8	0.0
Incr Delay (d2), s/veh	0.3	2.9	1.4	4.8	1.2	0.0	32.5	5.2	4.4	38.8	22.0	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	2.1	13.2	5.3	3.8	2.8	0.0	5.6	12.3	5.4	5.7	18.3	0.0
LnGrp Delay(d),s/veh	18.7	44.6	28.2	23.7	7.7	0.0	60.2	39.4	35.3	70.1	70.8	0.0
LnGrp LOS	B	D	C	C	A		E	D	D	E	E	
Approach Vol, veh/h		1194			817			1224			1241	
Approach Delay, s/veh		39.1			11.6			41.8			70.7	
Approach LOS		D			B			D			E	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	12.0	38.3	10.7	49.0	12.0	38.3	13.7	46.0
Change Period (Y+Rc), s	4.0	6.0	4.0	6.0	4.0	6.0	4.0	6.0
Max Green Setting (Gmax), s	8.0	32.0	10.0	40.0	8.0	32.0	10.0	40.0
Max Q Clear Time (g_c+I1), s	12.0	25.8	6.8	8.2	11.0	35.2	9.7	29.3
Green Ext Time (p_c), s	0.0	5.4	0.1	17.7	0.0	0.0	0.0	8.1

Intersection Summary	
HCM 2010 Ctrl Delay	43.6
HCM 2010 LOS	D

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	117	545	7	15	709	139	12	16	27	239	8	250
Future Volume (veh/h)	117	545	7	15	709	139	12	16	27	239	8	250
Number	1	6	16	5	2	12	3	8	18	7	4	14
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	0.96		0.85	0.93		0.83	1.00		0.62	0.70		0.77
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1757	1629	1000	1775	1582	1000	1183	1650	1000	1690	1574	1000
Adj Flow Rate, veh/h	127	592	8	16	771	151	13	17	29	260	9	272
Adj No. of Lanes	1	2	0	1	2	0	1	1	0	1	1	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	1	9	9	0	14	14	50	0	0	5	0	0
Cap, veh/h	423	1871	25	430	1231	241	120	128	218	321	11	331
Arrive On Green	0.05	0.60	0.59	1.00	1.00	1.00	0.33	0.33	0.32	0.33	0.33	0.32
Sat Flow, veh/h	1674	3118	42	721	2412	472	695	390	665	863	33	1012
Grp Volume(v), veh/h	127	294	306	16	480	442	13	0	46	260	0	281
Grp Sat Flow(s),veh/h/ln	1674	1547	1613	721	1503	1381	695	0	1055	863	0	1045
Q Serve(g_s), s	3.9	10.3	10.3	0.0	0.0	0.0	1.9	0.0	3.4	32.6	0.0	27.3
Cycle Q Clear(g_c), s	3.9	10.3	10.3	0.5	0.0	0.0	29.2	0.0	3.4	36.0	0.0	27.3
Prop In Lane	1.00		0.03	1.00		0.34	1.00		0.63	1.00		0.97
Lane Grp Cap(c), veh/h	423	928	968	430	767	705	120	0	345	321	0	342
V/C Ratio(X)	0.30	0.32	0.32	0.04	0.63	0.63	0.11	0.00	0.13	0.81	0.00	0.82
Avail Cap(c_a), veh/h	441	928	968	430	767	705	120	0	345	321	0	342
HCM Platoon Ratio	1.00	1.00	1.00	2.00	2.00	2.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	11.4	10.9	10.9	0.0	0.0	0.0	47.5	0.0	26.3	39.0	0.0	34.5
Incr Delay (d2), s/veh	0.4	0.9	0.9	0.2	3.8	4.2	0.4	0.0	0.2	14.3	0.0	14.7
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	1.8	4.6	4.8	0.0	0.8	0.8	0.4	0.0	1.0	9.1	0.0	9.2
LnGrp Delay(d),s/veh	11.7	11.8	11.7	0.2	3.8	4.2	47.9	0.0	26.4	53.2	0.0	49.2
LnGrp LOS	B	B	B	A	A	A	D		C	D		D
Approach Vol, veh/h		727			938			59			541	
Approach Delay, s/veh		11.7			3.9			31.2			51.2	
Approach LOS		B			A			C			D	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4		6		8
Phs Duration (G+Y+Rc), s	9.9	60.1		40.0		70.0		40.0
Change Period (Y+Rc), s	4.0	6.0		6.0		6.0		6.0
Max Green Setting (Gmax), s	7.0	53.0		34.0		64.0		34.0
Max Q Clear Time (g_c+I1), s	5.9	2.5		38.0		12.3		31.2
Green Ext Time (p_c), s	0.0	19.4		0.0		19.6		1.3

Intersection Summary	
HCM 2010 Ctrl Delay	18.4
HCM 2010 LOS	B

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	73	726	94	87	726	71	77	284	130	86	363	95
Future Volume (veh/h)	73	726	94	87	726	71	77	284	130	86	363	95
Number	1	6	16	5	2	12	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.99	1.00		0.99	1.00		0.99	1.00		0.99
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1757	1658	1000	1707	1637	1000	1775	1881	1591	1517	1900	1750
Adj Flow Rate, veh/h	79	789	102	95	789	77	84	309	141	93	395	103
Adj No. of Lanes	1	2	0	1	2	0	1	1	1	1	1	1
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	1	8	8	4	8	8	0	1	10	17	0	0
Cap, veh/h	230	1200	155	251	1247	122	262	599	426	277	624	484
Arrive On Green	0.04	0.43	0.41	0.02	0.14	0.14	0.05	0.32	0.32	0.06	0.33	0.33
Sat Flow, veh/h	1674	2800	362	1625	2859	279	1690	1881	1340	1445	1900	1474
Grp Volume(v), veh/h	79	444	447	95	429	437	84	309	141	93	395	103
Grp Sat Flow(s),veh/h/ln	1674	1575	1587	1625	1555	1583	1690	1881	1340	1445	1900	1474
Q Serve(g_s), s	3.0	24.7	24.7	3.7	28.6	28.6	3.7	14.7	8.8	4.9	19.4	5.6
Cycle Q Clear(g_c), s	3.0	24.7	24.7	3.7	28.6	28.6	3.7	14.7	8.8	4.9	19.4	5.6
Prop In Lane	1.00		0.23	1.00		0.18	1.00		1.00	1.00		1.00
Lane Grp Cap(c), veh/h	230	675	681	251	678	690	262	599	426	277	624	484
V/C Ratio(X)	0.34	0.66	0.66	0.38	0.63	0.63	0.32	0.52	0.33	0.34	0.63	0.21
Avail Cap(c_a), veh/h	267	675	681	275	678	690	287	599	426	284	624	484
HCM Platoon Ratio	1.00	1.00	1.00	0.33	0.33	0.33	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	21.4	25.0	25.2	21.1	38.8	38.8	26.3	30.6	28.6	25.3	31.3	26.7
Incr Delay (d2), s/veh	0.9	5.0	4.9	0.9	4.5	4.4	0.7	3.2	2.1	0.7	4.8	1.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	1.4	11.7	11.8	1.7	13.2	13.4	1.8	8.2	3.5	2.0	11.0	2.4
LnGrp Delay(d),s/veh	22.3	29.9	30.1	22.1	43.2	43.2	27.0	33.8	30.6	26.0	36.1	27.7
LnGrp LOS	C	C	C	C	D	D	C	C	C	C	D	C
Approach Vol, veh/h		970			961			534			591	
Approach Delay, s/veh		29.4			41.1			31.9			33.1	
Approach LOS		C			D			C			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	8.6	52.0	10.5	39.0	9.4	51.2	9.3	40.1
Change Period (Y+Rc), s	4.0	6.0	4.0	6.0	4.0	6.0	4.0	6.0
Max Green Setting (Gmax), s	7.0	43.0	7.0	33.0	7.0	43.0	7.0	33.0
Max Q Clear Time (g_c+I1), s	5.0	30.6	6.9	16.7	5.7	26.7	5.7	21.4
Green Ext Time (p_c), s	0.0	9.3	0.0	5.9	0.0	11.5	0.0	4.9

Intersection Summary	
HCM 2010 Ctrl Delay	34.2
HCM 2010 LOS	C

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	148	679	66	77	613	127	88	280	83	133	425	108
Future Volume (veh/h)	148	679	66	77	613	127	88	280	83	133	425	108
Number	1	6	16	5	2	12	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.90	0.97		0.94	0.97		0.82	0.92		0.90
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1690	1648	1000	1757	1707	1000	1455	1714	1000	1723	1690	1000
Adj Flow Rate, veh/h	161	738	72	84	666	138	96	304	90	145	462	117
Adj No. of Lanes	1	2	0	1	2	0	1	2	0	1	2	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	5	6	6	1	4	4	22	4	4	3	4	4
Cap, veh/h	293	1274	124	365	1105	229	217	692	196	321	744	186
Arrive On Green	0.15	0.89	0.86	0.03	0.28	0.27	0.06	0.29	0.27	0.02	0.10	0.09
Sat Flow, veh/h	1610	2851	278	1674	2641	546	1386	2379	675	1641	2482	621
Grp Volume(v), veh/h	161	405	405	84	408	396	96	204	190	145	297	282
Grp Sat Flow(s),veh/h/ln	1610	1566	1563	1674	1621	1567	1386	1629	1425	1641	1606	1497
Q Serve(g_s), s	6.5	6.3	6.6	3.2	24.0	24.1	5.4	11.2	12.1	6.9	19.5	19.9
Cycle Q Clear(g_c), s	6.5	6.3	6.6	3.2	24.0	24.1	5.4	11.2	12.1	6.9	19.5	19.9
Prop In Lane	1.00		0.18	1.00		0.35	1.00		0.47	1.00		0.41
Lane Grp Cap(c), veh/h	293	700	699	365	678	655	217	474	415	321	481	449
V/C Ratio(X)	0.55	0.58	0.58	0.23	0.60	0.60	0.44	0.43	0.46	0.45	0.62	0.63
Avail Cap(c_a), veh/h	293	700	699	383	678	655	229	474	415	321	481	449
HCM Platoon Ratio	2.00	2.00	2.00	0.67	0.67	0.67	1.00	1.00	1.00	0.33	0.33	0.33
Upstream Filter(I)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Uniform Delay (d), s/veh	18.6	3.6	3.8	18.2	31.7	31.9	27.9	31.6	32.3	28.0	43.5	43.8
Incr Delay (d2), s/veh	2.2	3.5	3.5	0.3	3.9	4.1	1.4	2.8	3.6	1.0	5.8	6.5
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	3.0	3.1	3.2	1.5	11.5	11.2	2.1	5.4	5.1	3.2	9.5	9.1
LnGrp Delay(d),s/veh	20.8	7.0	7.3	18.6	35.6	36.0	29.3	34.5	35.9	29.0	49.3	50.4
LnGrp LOS	C	A	A	B	D	D	C	C	D	C	D	D
Approach Vol, veh/h		971			888			490			724	
Approach Delay, s/veh		9.4			34.2			34.0			45.7	
Approach LOS		A			C			C			D	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2	3	4	5	6	7	8
Phs Duration (G+Y+Rc), s	12.0	50.0	12.0	36.0	8.8	53.2	11.1	36.9
Change Period (Y+Rc), s	4.0	6.0	4.0	6.0	4.0	6.0	4.0	6.0
Max Green Setting (Gmax), s	8.0	44.0	8.0	30.0	6.0	46.0	8.0	30.0
Max Q Clear Time (g_c+I1), s	8.5	26.1	8.9	14.1	5.2	8.6	7.4	21.9
Green Ext Time (p_c), s	0.0	11.5	0.0	6.6	0.0	17.8	0.0	4.2

Intersection Summary	
HCM 2010 Ctrl Delay	29.0
HCM 2010 LOS	C

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	0	1581	134	354	1000	0	96	0	431	1	1	0
Future Volume (veh/h)	0	1581	134	354	1000	0	96	0	431	1	1	0
Number	5	2	12	1	6	16	7	4	14	3	8	18
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		0.99	1.00		1.00	1.00		0.96	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1775	1810	1651	1690	1723	1000	1599	1542	1000	1000	1550	1000
Adj Flow Rate, veh/h	0	1718	146	385	1087	0	104	0	468	1	1	0
Adj No. of Lanes	1	2	1	1	2	0	1	1	0	0	1	0
Peak Hour Factor	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
Percent Heavy Veh, %	0	5	6	5	3	3	11	0	0	0	0	0
Cap, veh/h	65	1469	596	417	2173	0	277	0	331	49	28	0
Arrive On Green	0.00	0.43	0.43	0.22	0.66	0.00	0.26	0.00	0.25	0.26	0.26	0.00
Sat Flow, veh/h	492	3438	1395	1610	3360	0	1211	0	1255	0	107	0
Grp Volume(v), veh/h	0	1718	146	385	1087	0	104	0	468	2	0	0
Grp Sat Flow(s),veh/h/ln	492	1719	1395	1610	1637	0	1211	0	1255	107	0	0
Q Serve(g_s), s	0.0	47.0	7.4	21.2	18.4	0.0	0.0	0.0	29.0	0.0	0.0	0.0
Cycle Q Clear(g_c), s	0.0	47.0	7.4	21.2	18.4	0.0	12.1	0.0	29.0	29.0	0.0	0.0
Prop In Lane	1.00		1.00	1.00		0.00	1.00		1.00	0.50		0.00
Lane Grp Cap(c), veh/h	65	1469	596	417	2173	0	277	0	331	77	0	0
V/C Ratio(X)	0.00	1.17	0.24	0.92	0.50	0.00	0.38	0.00	1.41	0.03	0.00	0.00
Avail Cap(c_a), veh/h	65	1469	596	417	2173	0	277	0	331	77	0	0
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Upstream Filter(I)	0.00	1.00	1.00	1.00	1.00	0.00	1.00	0.00	1.00	1.00	0.00	0.00
Uniform Delay (d), s/veh	0.0	31.5	20.1	33.8	9.3	0.0	34.3	0.0	41.5	33.2	0.0	0.0
Incr Delay (d2), s/veh	0.0	84.0	1.0	26.2	0.8	0.0	3.9	0.0	203.7	0.6	0.0	0.0
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.0	39.4	3.0	14.4	8.4	0.0	3.0	0.0	28.7	0.1	0.0	0.0
LnGrp Delay(d),s/veh	0.0	115.5	21.1	60.0	10.1	0.0	38.1	0.0	245.2	33.8	0.0	0.0
LnGrp LOS		F	C	E	B		D		F	C		
Approach Vol, veh/h		1864			1472			572			2	
Approach Delay, s/veh		108.1			23.2			207.5			33.8	
Approach LOS		F			C			F			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4		6		8
Phs Duration (G+Y+Rc), s	26.0	51.0		33.0		77.0		33.0
Change Period (Y+Rc), s	4.0	6.0		6.0		6.0		6.0
Max Green Setting (Gmax), s	22.0	45.0		27.0		71.0		27.0
Max Q Clear Time (g_c+I1), s	23.2	49.0		31.0		20.4		31.0
Green Ext Time (p_c), s	0.0	0.0		0.0		44.0		0.0

Intersection Summary	
HCM 2010 Ctrl Delay	90.6
HCM 2010 LOS	F

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	62	147	87	424	360	198	49	391	219	101	452	90
Future Volume (veh/h)	62	147	87	424	360	198	49	391	219	101	452	90
Number	3	8	18	7	4	14	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	1.00		1.00	1.00		1.00	1.00		0.99	1.00		0.99
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1690	1589	1000	1723	1537	1000	1543	1727	1667	1740	1525	1000
Adj Flow Rate, veh/h	62	147	87	424	360	198	49	391	219	101	452	90
Adj No. of Lanes	1	1	0	1	1	0	1	1	1	1	1	0
Peak Hour Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Percent Heavy Veh, %	5	2	2	3	7	7	15	10	5	2	9	9
Cap, veh/h	84	187	111	347	363	199	251	733	564	424	541	108
Arrive On Green	0.20	0.20	0.18	0.14	0.39	0.37	0.12	0.85	0.80	0.05	0.44	0.42
Sat Flow, veh/h	769	935	554	1641	933	513	1470	1727	1403	1657	1235	246
Grp Volume(v), veh/h	62	0	234	424	0	558	49	391	219	101	0	542
Grp Sat Flow(s),veh/h/ln	769	0	1489	1641	0	1446	1470	1727	1403	1657	0	1480
Q Serve(g_s), s	0.4	0.0	13.5	13.0	0.0	34.6	1.5	5.6	4.0	3.2	0.0	29.2
Cycle Q Clear(g_c), s	18.0	0.0	13.5	13.0	0.0	34.6	1.5	5.6	4.0	3.2	0.0	29.2
Prop In Lane	1.00		0.37	1.00		0.35	1.00		1.00	1.00		0.17
Lane Grp Cap(c), veh/h	84	0	298	347	0	562	251	733	564	424	0	649
V/C Ratio(X)	0.74	0.00	0.79	1.22	0.00	0.99	0.19	0.53	0.39	0.24	0.00	0.83
Avail Cap(c_a), veh/h	84	0	298	347	0	562	275	733	564	446	0	649
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00	2.00	1.00	1.00	1.00
Upstream Filter(I)	1.00	0.00	1.00	1.00	0.00	1.00	1.00	1.00	1.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	45.0	0.0	34.5	28.1	0.0	27.7	15.8	4.3	5.6	14.4	0.0	22.5
Incr Delay (d2), s/veh	44.7	0.0	18.6	123.2	0.0	36.2	0.4	2.8	2.0	0.3	0.0	12.1
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	2.6	0.0	7.1	21.5	0.0	19.3	0.6	3.0	1.8	1.5	0.0	14.1
LnGrp Delay(d),s/veh	89.7	0.0	53.1	151.3	0.0	63.9	16.2	7.1	7.6	14.7	0.0	34.6
LnGrp LOS	F		D	F		E	B	A	A	B		C
Approach Vol, veh/h		296			982			659			643	
Approach Delay, s/veh		60.8			101.7			8.0			31.5	
Approach LOS		E			F			A			C	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4	5	6	7	8
Phs Duration (G+Y+Rc), s	8.8	42.2		39.0	7.5	43.5	17.0	22.0
Change Period (Y+Rc), s	4.0	6.0		6.0	4.0	6.0	4.0	6.0
Max Green Setting (Gmax), s	6.0	35.0		33.0	5.0	36.0	13.0	16.0
Max Q Clear Time (g_c+I1), s	5.2	7.6		36.6	3.5	31.2	15.0	20.0
Green Ext Time (p_c), s	0.0	9.7		0.0	0.0	3.1	0.0	0.0

Intersection Summary	
HCM 2010 Ctrl Delay	55.5
HCM 2010 LOS	E

Movement	EBL	EBT	EBR	WBL	WBT	WBR	NBL	NBT	NBR	SBL	SBT	SBR
Lane Configurations												
Traffic Volume (veh/h)	35	41	38	121	97	59	42	628	82	44	746	33
Future Volume (veh/h)	35	41	38	121	97	59	42	628	82	44	746	33
Number	7	4	14	3	8	18	5	2	12	1	6	16
Initial Q (Qb), veh	0	0	0	0	0	0	0	0	0	0	0	0
Ped-Bike Adj(A_pbT)	0.99		0.99	0.99		0.98	1.00		1.00	1.00		1.00
Parking Bus, Adj	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Adj Sat Flow, veh/h/ln	1757	1573	1000	1659	1602	1000	1599	1528	1000	1740	1530	1000
Adj Flow Rate, veh/h	35	41	38	121	97	59	42	628	82	44	746	33
Adj No. of Lanes	1	1	0	1	1	0	1	1	0	1	1	0
Peak Hour Factor	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Percent Heavy Veh, %	1	2	2	7	0	0	11	8	8	2	8	8
Cap, veh/h	206	152	141	263	189	115	479	770	100	282	847	37
Arrive On Green	0.20	0.20	0.20	0.20	0.20	0.20	0.04	0.58	0.58	0.07	1.00	1.00
Sat Flow, veh/h	1144	748	694	1161	927	564	1523	1324	173	1657	1454	64
Grp Volume(v), veh/h	35	0	79	121	0	156	42	0	710	44	0	779
Grp Sat Flow(s),veh/h/ln	1144	0	1442	1161	0	1490	1523	0	1496	1657	0	1518
Q Serve(g_s), s	2.5	0.0	4.2	8.8	0.0	8.4	1.0	0.0	34.0	0.9	0.0	0.0
Cycle Q Clear(g_c), s	10.9	0.0	4.2	13.0	0.0	8.4	1.0	0.0	34.0	0.9	0.0	0.0
Prop In Lane	1.00		0.48	1.00		0.38	1.00		0.12	1.00		0.04
Lane Grp Cap(c), veh/h	206	0	294	263	0	304	479	0	870	282	0	884
V/C Ratio(X)	0.17	0.00	0.27	0.46	0.00	0.51	0.09	0.00	0.82	0.16	0.00	0.88
Avail Cap(c_a), veh/h	304	0	417	362	0	431	509	0	870	312	0	884
HCM Platoon Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	2.00	2.00	2.00
Upstream Filter(I)	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00	1.00	0.00	1.00
Uniform Delay (d), s/veh	36.7	0.0	30.2	35.7	0.0	31.9	6.8	0.0	15.0	13.0	0.0	0.0
Incr Delay (d2), s/veh	0.4	0.0	0.5	1.3	0.0	1.3	0.1	0.0	8.3	0.3	0.0	12.3
Initial Q Delay(d3),s/veh	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
%ile BackOfQ(50%),veh/ln	0.8	0.0	1.7	2.9	0.0	3.5	0.4	0.0	15.8	0.4	0.0	3.0
LnGrp Delay(d),s/veh	37.1	0.0	30.7	36.9	0.0	33.2	6.8	0.0	23.3	13.3	0.0	12.3
LnGrp LOS	D		C	D		C	A		C	B		B
Approach Vol, veh/h		114			277			752			823	
Approach Delay, s/veh		32.7			34.8			22.4			12.3	
Approach LOS		C			C			C			B	

Timer	1	2	3	4	5	6	7	8
Assigned Phs	1	2		4	5	6		8
Phs Duration (G+Y+Rc), s	7.3	58.3		24.3	7.3	58.4		24.3
Change Period (Y+Rc), s	4.0	6.0		6.0	4.0	6.0		6.0
Max Green Setting (Gmax), s	5.0	43.0		26.0	5.0	43.0		26.0
Max Q Clear Time (g_c+I1), s	12.9	36.0		12.9	3.0	2.0		15.0
Green Ext Time (p_c), s	0.0	5.4		2.0	0.0	18.6		1.9

Intersection Summary	
HCM 2010 Ctrl Delay	20.5
HCM 2010 LOS	C

5 PHASE ONE POLICY AND TECHNICAL SUMMARY

TRANSPORTATION MASTER PLAN
LOOKING AHEAD

THE CITY OF Waterloo

Summary Report

Date: February 27, 2020

To: Christopher Hodgson, City of Waterloo

From: Gene Chartier, Paradigm Transportation Solutions Limited

c.c.: Kate Whitfield, Alta Planning + Design
Susan Hall, Lura Consulting

Re: **Phase One Policy and Technical Summary**

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1 Introduction

This report summarizes the policy and technical analysis carried out during Phase One of the **City of Waterloo Transportation Master Plan (TMP) Update**. The document is organized as follows:

- Chapter 2 outlines the policy context for the TMP Update and highlights the three overarching documents with the most significant influence;
- Chapter 3 summarizes the current state of travel behaviour in the City and relevant changes since the 2011 TMP was completed;
- Chapter 4 presents current Levels of Service at key intersections and changes since the 2011 TMP was completed.

2 Policy Context

2.1 Policy Framework

The TMP Update is based on the land use and transportation planning policy context defined by the City of Waterloo, Region of Waterloo, Province of Ontario and other public agencies, many of which have changed since the 2011 TMP was completed. **Figure 1** summarizes the myriad municipal and provincial plans and policies informing the update.

Province of Ontario	Region of Waterloo and Other Agencies	City of Waterloo
Provincial Policy Statement *Places to Grow Act, 2005* and Growth Plan for the Greater Golden Horseshoe *Accessibility for Ontarians with Disabilities Act* Metrolinx 2041 Regional Transportation Plan MTO Transit Supportive Guidelines #CycleON Ontario Trails Strategy	Region of Waterloo Official Plan Region of Waterloo Transportation Master Plan Walk Cycle Waterloo Region	City of Waterloo Official Plan City of Waterloo Strategic Plan City of Waterloo Transportation Master Plan (2011) Northdale Land Use and Community Improvement Plan Study Uptown Public Realm Strategy Rapid Transit Station Area Plans

Figure 1: Policy Framework

2.2 City of Waterloo Strategic Plan

The City of Waterloo Strategic Plan identifies the goals and priorities of the community over the 2019 to 2022 term of City Council. The plan also serves as a corporate strategy for the City, helping to guide how the municipality operates and delivers its services.

The Strategic Plan sets out the following vision for Waterloo:

Waterloo is an equitable community that leads the world in learning, discovery and caring.

Building from the vision, the plan identifies the following six strategic pillars or areas of focus, which are guided by the principles of equity and inclusion, sustainability, fiscal responsibility, healthy and safe workplace, effective engagement, personal leadership and service excellence:

- Equity, inclusion, and a sense of belonging;
- Sustainability and the environment;
- Safe, sustainable transportation;
- Healthy community and resilient neighbourhoods;
- Infrastructure renewal; and
- Economic growth and development.

The Strategic Plan identifies **safe, sustainable transportation** as a strategic pillar. This condition "exists when all users and all modes of transportation are able to share roadways and trail systems safely; when traffic speeds respect the safety of the community; when policy and planning supports the development and maintenance of sustainable infrastructure; and when more residents are able to rely on sustainable modes of transportation such as public transit or active transportation to get where they

need to go"[1]. The end goal is to improve all modes of transportation thereby making Waterloo more mobile, accessible and connected.

2.3 City of Waterloo Official Plan

The Official Plan is the City's long-range, comprehensive municipal planning document, providing a framework for land use decision-making in the City of Waterloo. The Plan sets a broad, coordinated vision for all lands within the City, and supports the overall goal of achieving a healthy community built on the principles of diversity and adaptability, accessibility and equity, connectivity, health and vitality.

Section 2.3 of the document identifies the following transportation objectives considered to have a significant influence on the land use policies and designations of the Plan:

- Encourage active transportation as an alternative to the automobile;
- Plan for and support a shift in focus from providing roads to move cars, to providing streets where people can interact and travel on, whether by foot, bicycle, transit or other motorized vehicle;
- Support and contribute to the success of the public transit system;
- Continue to provide bicycle and vehicular parking that meets community needs while balancing needs of motorists and active transportation users; and
- Plan for trails and open space networks and supporting facilities that are interconnected and service transportation functions.

Achieving a healthy and livable City and a transportation system that is sustainable into the future will require placing increased emphasis on moving people –managing travel in order to reduce reliance on the automobile in favour of transit and more active forms of movement such as walking and cycling. Chapter 6 of the Plan outlines the following key areas of focus when planning for the most efficient use of new and existing networks that support this transportation system vision:

- Ensuring compact, mixed-use land use patterns, providing people with the opportunity to live close to where they are working, learning, shopping and playing;
- Planning for a comprehensive, multi-modal, well-connected transportation system that offers safe and convenient alternatives to automobile travel;
- Planning for safe and convenient pedestrian and cyclist movement, giving priority to these travel modes in the planning, design and operation of the City's networks (road and trails/open space) as well as in the design of sites and buildings;
- Increasing the proportion of trips made by transit travel by planning for a more compact, mixed-use City form that supports a comprehensive and efficient transit system, including rapid transit; and
- Planning for the provision of appropriate bicycle and vehicular parking, balancing the desire for convenience with the desire to reduce automobile reliance.

[1] City of Waterloo. https://www.waterloo.ca/en/government/strategic-plan.aspx

2.4 Region of Waterloo Transportation Master Plan

The 2018 Regional Transportation Master Plan Update (2018 RTMP)[2] is the third version of the Region of Waterloo's long-term transportation strategy. This strategic document outlines the needs for active transportation (cycling and walking), public transit, and Regional roads to the year 2041. The plan includes a series of Regional policies to encourage and shape sustainable travel and economic growth, support land-use planning, and aid the Region in becoming "a community where people matter and ideas grow."

To realize the vision set out in the 2018 RTMP, transportation goals and actions of the lower-tier municipalities, including the City of Waterloo, must align with the directions set out in the Regional document. For the City, this includes:

- Pursuing actions where the City is identified to take the lead role;
- Referencing and incorporating (where appropriate) the 2018 RTMP road, active transportation and transit network plans;
- Providing connections (where possible) between City and Regional infrastructure to create a seamless transportation network; and
- Considering protected cycling facilities along City roadways to align with the broader vision for the Region.

3 Travel Behaviour

3.1 Current Trends

City-wide travel characteristics were studied based on data collected through the 2011 and 2016 Transportation Tomorrow Survey (TTS). The TTS is a confidential and voluntary survey on how Ontarians in the Greater Golden Horseshoe (GGH) travel. The research helps local and regional governments, as well as the province and its agencies, make better informed transportation planning and investment decisions.

Several trip making characteristics were extracted from the 2016 TTS to help explain current travel trends in the City. The following observations were noted from the data:

Trip Destination

Residents of Waterloo travel mostly to points within the City. The City of Kitchener is the next most common destination.

Trip Purpose

Approximately 40% of daily trips originating in the City are made for home-based discretionary purposes. Home-based work (29%), non home-based (18%) and home-based school (14%) are the next most common trip purposes.

[2] IBI Group. *Region of Waterloo Moving Forward: 2018 Transportation Master Plan.* June 2019.

Travel Mode

Private auto driver (67%) and passenger (13%) are the most common travel modes for trips originating in the City, followed by walking (7%), public transit (7%) and cycling (3%).

Trip Length

The length of trips originating in the City of Waterloo were examined to assess the potential for increased walking and cycling use. In most cases, trips less than 2 km can be made effectively by walking, while cycling is a viable travel mode for trips up to 8 km. According to the 2016 TTS data, approximately 75% of all trips on a typical weekday in the City of Waterloo are within cycling distance, but only 13% are made using active modes.

3.2 Change Over Time

Monitoring travel behaviour changes over time enables the City to assess the effectiveness of the TMP in achieving objectives and identify needed policy adjustments. The following discusses changes observed between 2011 and 2016 with a focus on the most significant shifts noted in active transportation use.

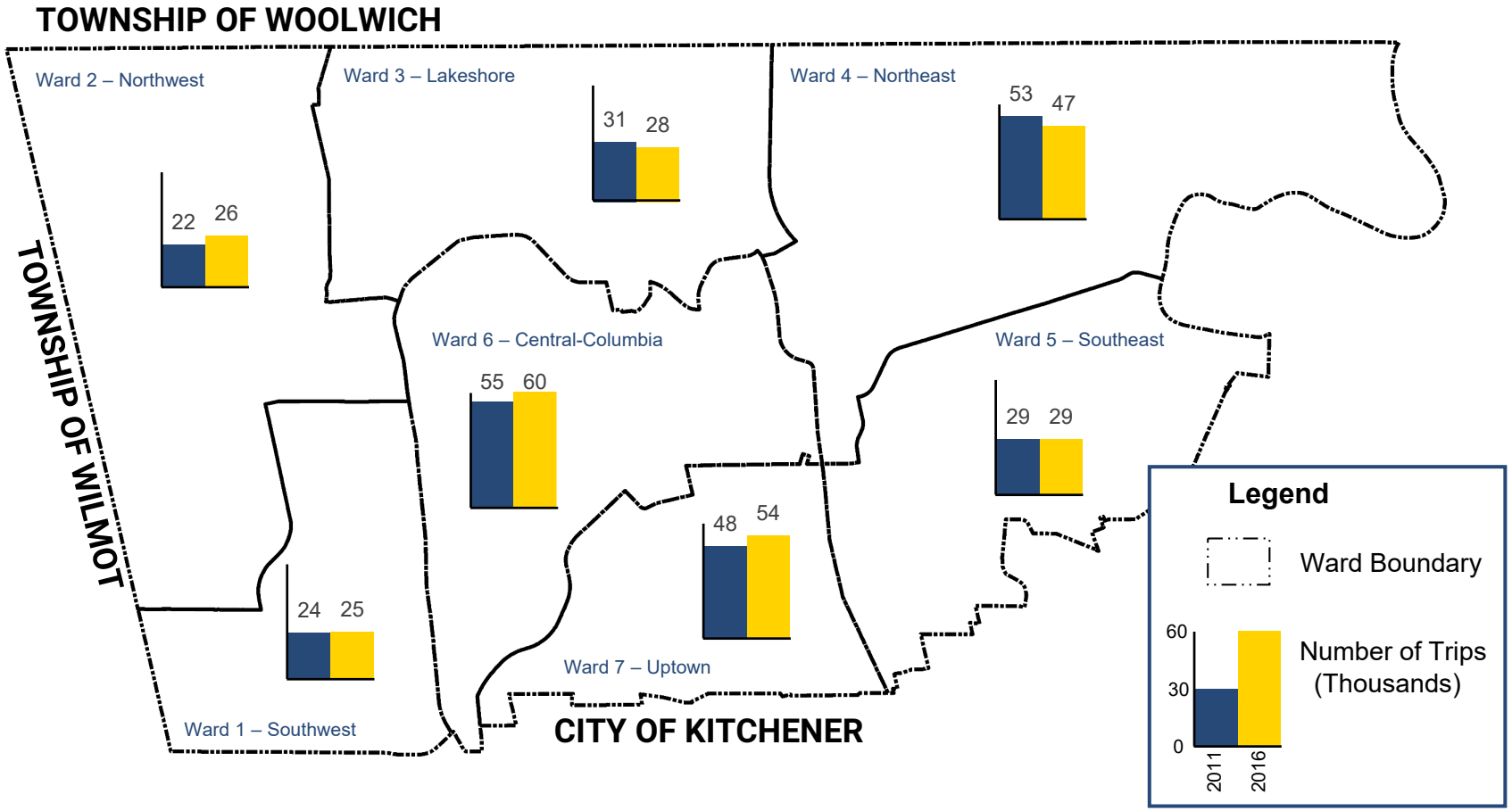
Socio-Demographic Characteristics

The following details the change in key socio-demographic characteristics observed in the City between 2011 and 2016 based on data from the Statistics Canada Census of Population and TTS:

- Population grew by 6.3% or 1.2% per annum. The male population rose at a greater rate (7.4%) than female (5.2%). The median age of Waterloo residents increased only slightly (0.1 years). Ward 1 and Ward 3 populations decreased by 10% and 24% respectively, while Ward 2 and Ward 6 expanded by approximately 15%. Ward 7 experienced the most significant population growth at almost 40%.
- Number of households in Waterloo grew at a faster rate (7.6% or 1.5% per annum) than the City's population. While the proportion of households owning their dwelling did not increase significantly (0.6%), the number of households renting rose considerably (27.2%). Average household size did not change, while average total household income (before tax) increased by nearly $8,000. While population and households increased, vehicle ownership decreased (-3.1%); and
- Labour force in Waterloo grew at a slower pace (3.7%) than the City's population, which resulted in a slightly lower participation rate (-2.8%). Employed labour force grew at a faster pace (4.1%) than the total, but still caused a decline in the employment rate (-2.4%). The number of jobs in the City increased (4.8%), resulting in minimal change to the labour force-employment ratio (-1.0%).

Daily Trips

Figure 2 compares the total daily trips made in the City in 2011 and 2016 by ward. During this period, the number of trips made by Waterloo residents increased at a greater rate (9.6%) than population growth (6.3%).



TOTAL DAILY TRIPS BY WARD, 2011-2016

Figure 2

Trip Purpose and Length

Figure 3 shows the change in the number of daily trips by purpose between 2011 and 2016. Only non home-based trips decreased over the five-year period. Additionally, the average trip length has increased for all trip purposes. As a result, the average length of trips originating in the City of Waterloo was 8.7 km in 2016 compared to 8.2 km in 2011.

Mode Share

Table 1 summarizes the change in mode share between 2011 and 2016. Of note, the auto passenger and driver mode shares decreased by 3% each. This is attributed to the growth in active transportation use, with walking and cycling mode shares increasing by 3% and 2%, respectively.

Figure 4 shows the percentage of total daily trips within cycling distance for each ward, plus the active transportation (walking and cycling) mode shares. The active transportation mode share of trips less than or equal to 8 km increased in each of the seven wards in the City, except Ward 1. The more densely populated central wards still exhibited the highest active transportation mode share in 2016.

Table 1: Change in Mode Share, 2011-2016

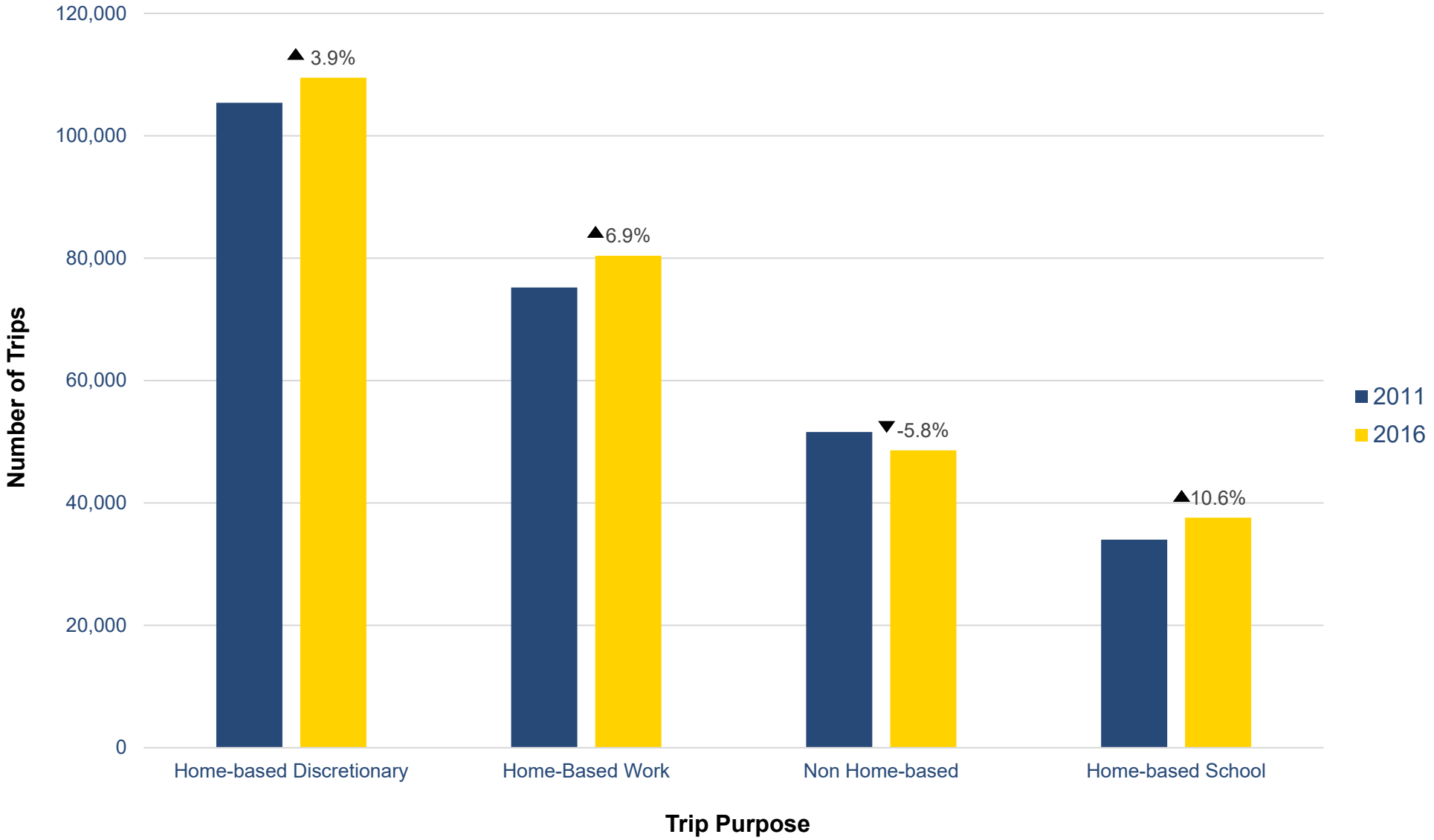
Mode	Year		Change
	2011	2016	
Walk	4%	7%	3%
Cycle	1%	3%	2%
Transit	7%	7%	0%
Auto Passenger	16%	13%	-3%
Auto Driver	70%	67%	-3%
Other	2%	3%	1%

Source: 2011 and 2016 Transportation Tomorrow Survey

3.3 Potential Impact of Transportation Innovation

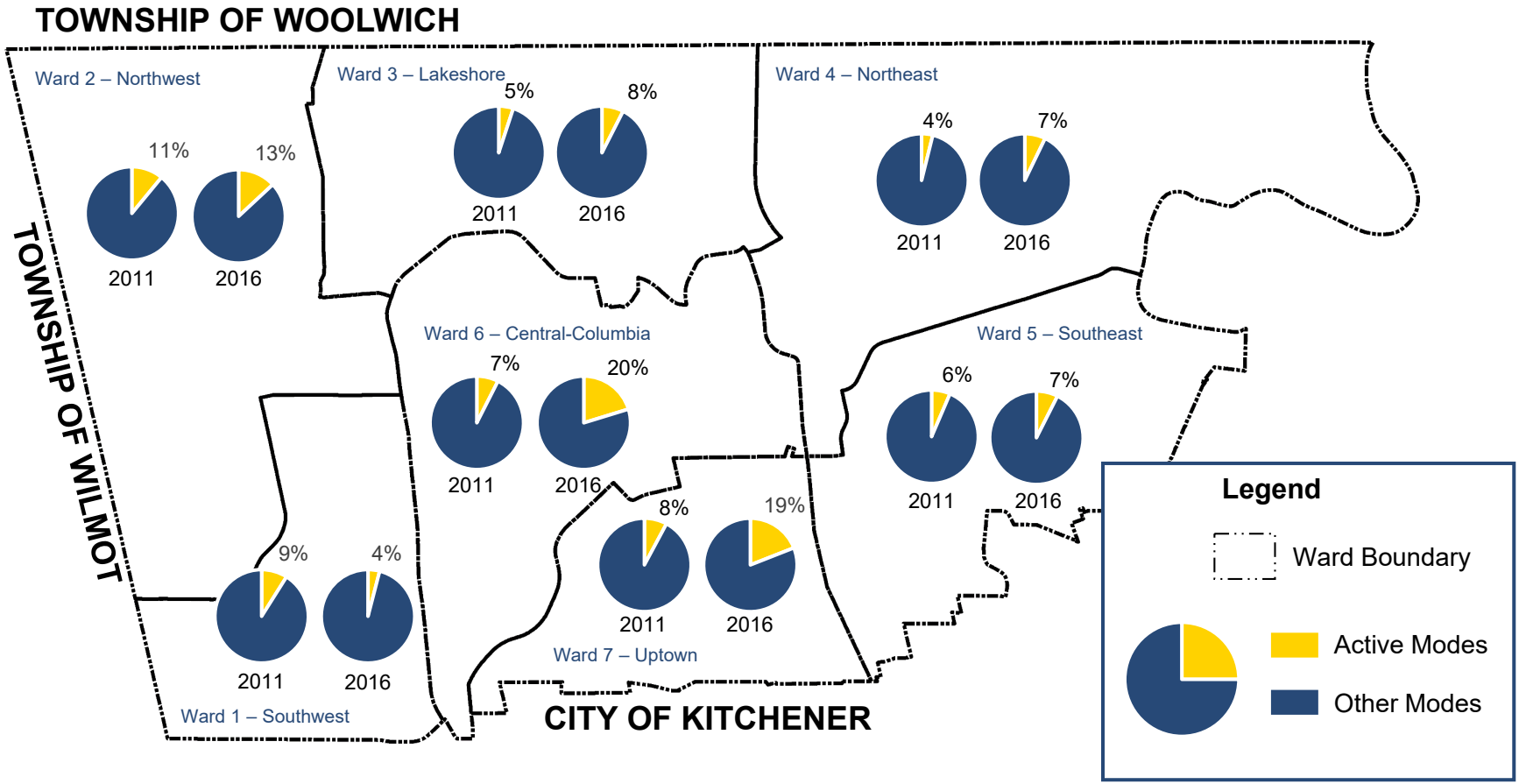
Travel behaviour in Waterloo can be expected to change over time as a result of key infrastructure investments, transformative technologies and emerging government regulation and policies. Within the horizon of the TMP Update (and beyond), the following initiatives have arguably the greatest potential to influence travel trends in the City:

- **ION Light Rail Transit** – Last year's opening of the ION LRT service is expected to increase transit mode share in the City of Waterloo, as well as active transportation use as more riders are likely to walk or cycle to the stations than drive given their locations and configuration. Initiatives by the City and Region to improve cycling facilities and provide pedestrian links to the ION LRT stations have helped to remove physical barriers to active transportation access, further spurring travel by these modes. Additionally, Grand River Transit has redesigned its bus network in the City to effectively extend the catchment area of the ION LRT service into Wards 1, 2 and 5. This is expected to increase transit and active transportation use in these wards as well, as riders can easily walk and cycle to nearby bus stops.



TOTAL DAILY TRIPS BY PURPOSE, 2011-2016

Figure 3



ACTIVE TRANSPORTATION MODE SHARE OF TRIPS 8 KM OR LESS BY WARD, 2011-2016

Figure 4

- **Ridesharing and Shared Mobility** – Combining ride-hailing services with the public transit system has the potential to offer a user friendly and cost-effective option for travel to lower density and other underserved locations. This could ultimately reduce SOV trips.
- **Bike-Sharing and E-Bikes** – A bike-sharing service in the City of Waterloo with both conventional bicycles and electric bikes would provide residents with another viable alternative to the SOV. Given the number of trips in the City under 8 km in length, and the high percentage of those trips currently being made by automobile, the potential exists to grow the share of travel by active modes. The greatest opportunity for a bikeshare system exists in the Uptown area and near the universities.

4 Intersection Level of Service

Traffic operations at 47 major intersections in Waterloo were analyzed to provide a snapshot of current traffic flow on the road network serving the City. The results were compared to findings from the 2011 TMP to assess change over time.

Level of service (LOS) is a qualitative measure used to describe traffic flow at an intersection. The LOS denotes how well a vehicle movement (or the entire intersection) operates by assigning quality levels based on the delay experienced by drivers. **Table 2** describes the different LOS in general terms and provides data concerning delays.

Table 2: Level of Service Descriptions

Level of Service	General Description	Average Control Delay (seconds/vehicle)
A	Free flow	0 to 10
B	Stable flow (slight delays)	> 10 to 20
C	Stable flow (acceptable delays)	> 20 to 35
D	Approaching unstable flow (tolerable delay, occasionally wait through more than one signal cycle before proceeding)	> 35 to 55
E	Unstable flow (intolerable delay)	> 55 to 80
F	Forced flow (congested and queues fail to clear)	> 80

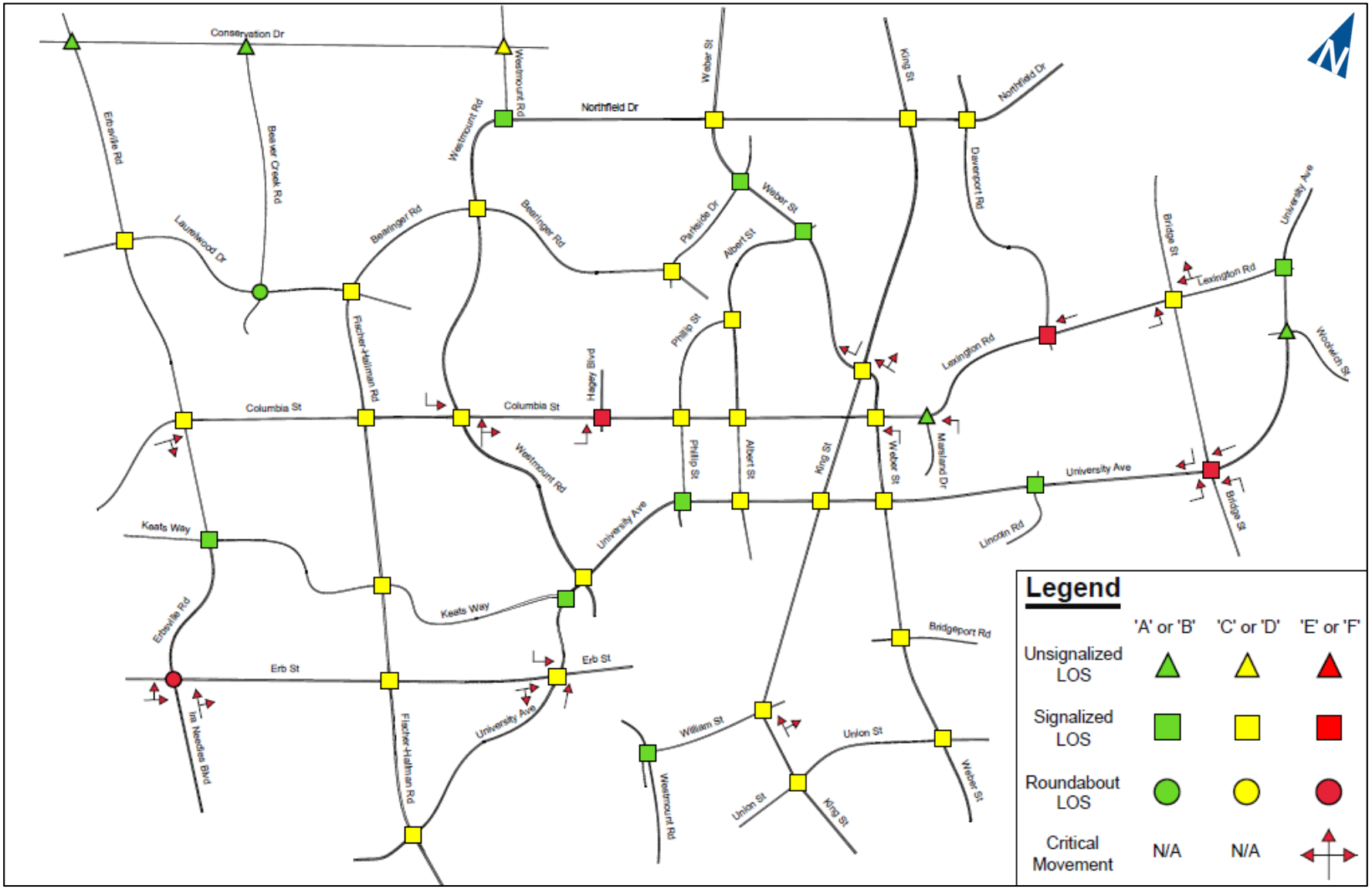
Volume to capacity (v/c) ratios provide another indicator of operational efficiency. The v/c ratio represents the sufficiency of an intersection to accommodate the vehicular demand (v) based on the capacity (c), which is defined as the maximum rate at which vehicles can pass through a given point in an hour under prevailing conditions. As the v/c ratio approaches 1.0, traffic flow may become unstable, and delay and queuing conditions may occur. Once the demand exceeds the capacity (a v/c ratio greater than 1.0), traffic flow is unstable and excessive delay and queuing is expected.

Using these indicators and criteria, weekday AM and PM peak hour traffic conditions at the 40 signalized, five unsignalized and two roundabout intersections were analyzed to identify any existing operational deficiencies. For the purpose of the analyses, intersections and/or their individual movements experiencing a LOS E or F and/or a v/c ratio of 0.9 or greater were considered critical.

Figure 5 illustrates the critical movements for the AM peak hour. A total of 12 intersections operate or have movements (23 movements) that operate at critical levels of service. By comparison, only seven movements at five intersections were considered critical based on the 2008 counts reported in 2011 TMP.

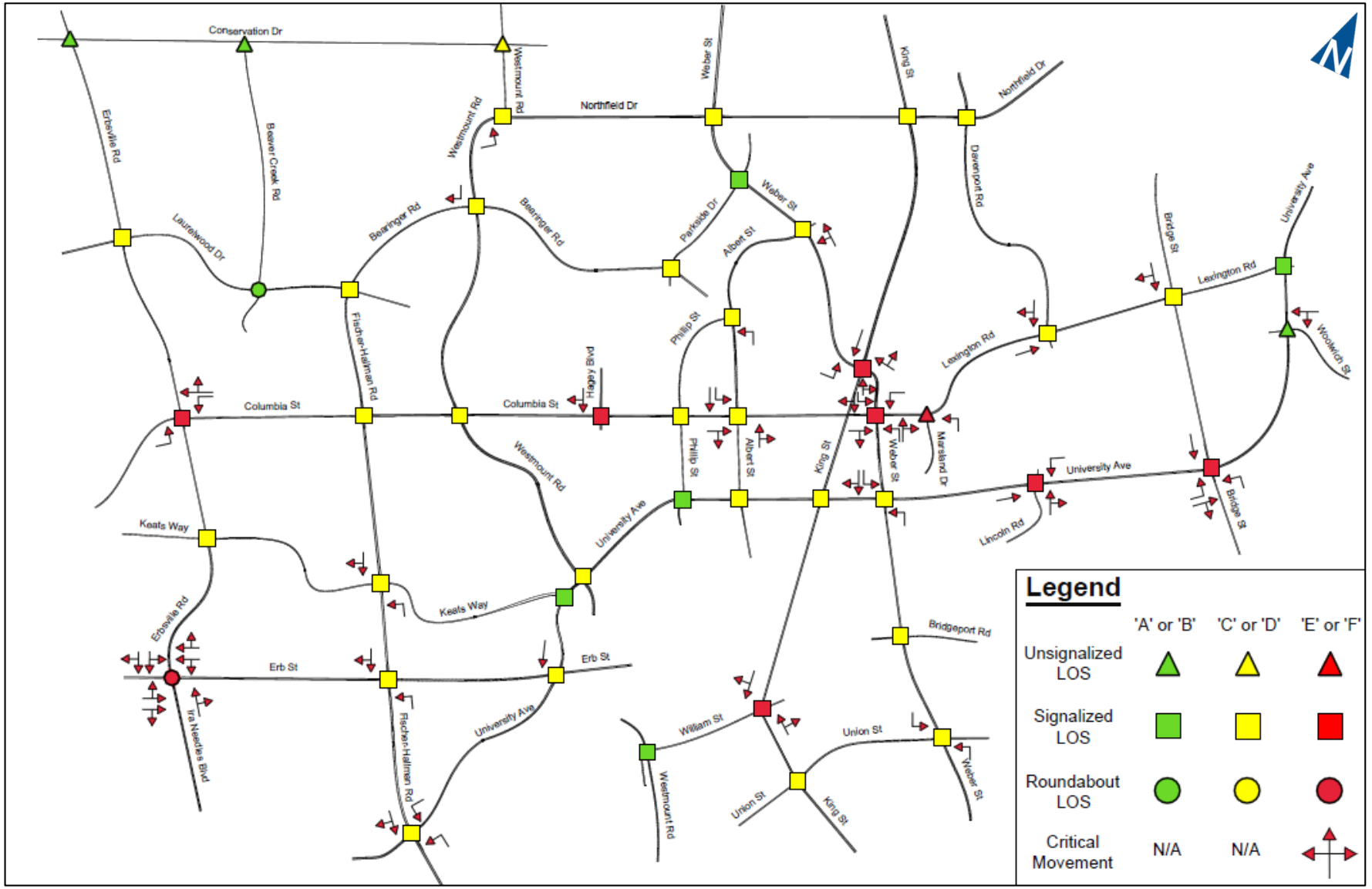
Figure 6 illustrates the critical movements for the PM peak hour. A total of 23 intersections operate or have individual movements (56 movements) that operate at critical levels of service. By comparison, only nine movements at eight intersection were considered critical based on the 2008 counts reported in 2011 TMP.

Overall, the afternoon peak hour experiences worse levels of service than the morning due to higher traffic volumes, owing to more discretionary trips being made (i.e. work to home with shopping, recreation, social, etc.).



EXISTING WEEKDAY AM PEAK HOUR INTERSECTION LEVEL OF SERVICE

Figure 5



EXISTING WEEKDAY PM PEAK HOUR INTERSECTION LEVEL OF SERVICE

Figure 6

6 REGION OF WATERLOO TRAVEL DEMAND FORECASTING MODEL

Technical Memorandum

Date: April 29, 2020

To: Christopher Hodgson, City of Waterloo

From: Gene Chartier, Paradigm Transportation Solutions Limited

c.c.: Kate Whitfield, Alta Planning + Design
Susan Hall, Lura Consulting

Re: **Region of Waterloo Travel Demand Forecasting Model**

---

1 Introduction

This memorandum provides an overview of the Region of Waterloo Travel Demand Forecasting Model (the Model), its applicability for the **City of Waterloo Transportation Master Plan (TMP) Update**, and the direction taken regarding use of the Model in developing the plan.

2 Overview

The Region of Waterloo Travel Demand Forecasting Model (the Model) forecasts transportation trip-making by mode and trip purpose across the Region. It is a macro level tool built on the VISUM software platform that assesses how well roads function based on estimated vehicular demand and capacity and has historically been used to identify roads that require widening (i.e. two traffic lanes to four traffic lanes) due to forecasted growth. This information is utilized in the capital budget and development charge background study. The Model has also been used to assess alternative growth and mode choice scenarios, but primarily to examine impacts to the road network.

The Model relies on population and employment forecasts generated by the Region to project future travel demands. These forecasts ultimately translate into person trips by various travel modes on the transportation network as people move to, from and within the Region of Waterloo.

The City of Waterloo TMP Update anticipated a review and application of the Model to help identify any City roads that would see future capacity pressures due to forecasted growth in population and employment. The Model was also planned to be used to assess potential mode choice assumptions in the Business as Usual (BAU) analysis.

3 Issues

Prior to commencing the modelling task, the Project Team reviewed key inputs and assumptions used in the Model for consistency and suitability in the City's context. Through this review, discrepancies between the Regional population and employment forecasts used in the Model and what the City is observing in terms of actual growth were noted. Two specific areas of concern were identified:

- The forecasts appear to underrepresent the amount of growth occurring in some transit station areas in Waterloo; and
- The forecasts contained a more modest growth target for 2041 than is currently envisioned in the most recent growth plan for the Greater Golden Horseshoe and are not consistent with assumptions used for other City master plans.

The discrepancies raise questions around the reliability of the forecasts and their ability to inform the TMP and the capital program. From a financial and asset management perspective, the capital and operating costs to widen roads can be significant. Given the potential impact, decisions related to road widenings should be based on data in which staff has greater confidence in.

A further task of the TMP was to use the Model to analyze existing and projected traffic conditions to help establish corporate targets for reducing Carbon Dioxide (CO_2) emissions. The above noted discrepancies would also make the setting of such targets questionable and potentially unusable.

4 Options Considered

The Project Team considered several options to address this issue, including but not limited to:

- Using the current Regional population and employment forecasts but including a caveat that the data has limitations;
- Developing and testing alternative population and employment forecast(s) using the Model;
- Applying a growth factor (+ve or -ve) to the model traffic volumes to account for the discrepancy between the Regional forecasts and observed growth;
- Relying on the work completed for other studies; and
- Proceeding with the remainder of the TMP work that does not rely on the Model and revisiting the demand forecasting component when updated population and employment figures become available.

The pros and cons of each option were considered based on several factors, including:

- Impact on Reliability and/or Accuracy of the Data;
- Timetable – A review of the Regional Official Plan (ROP) is currently underway and Regional staff has advised updated municipal forecasts are anticipated in 1 to 2 years versus the TMP Update completion target of Spring 2020;
- Council Feedback from the September 9, 2019 TMP Workshop – During the workshop, Council positioned that widening roads for more traffic is not necessarily in alignment with the Official Plan and "Complete Streets" approach.; and

- Local Transportation/Land Use Policies – The majority of population and employment growth in Waterloo is planned to occur around designated Nodes and Corridors and ION stations. These areas are typically served by Regional roads or local roads where the City's priority would be repurposing the existing available municipal right-of-way for non-auto modes, not through road widening.

5 Recommended Approach

Given the above factors, the Project Team concluded the modelling task should not be completed as part of the TMP Update and should be deferred and carried out as a separate future project once the Regional Official Plan (ROP) is updated. The new ROP will provide updated population and employment forecasts for the City, which can then be applied in the Model. The analysis, targets for modal shift and CO2 reduction, can then be completed with confidence.

The final TMP Update report will make a recommendation for the modelling work and other technical analyses to be commenced upon completion of the ROP update. This information will inform the next update of the City's Official Plan.

7 ROAD CLASSIFICATION

Technical Memorandum

Date: March 18, 2020

To: Christopher Hodgson, City of Waterloo

From: Gene Chartier, Paradigm Transportation Solutions Limited

c.c.: Kate Whitfield, Alta Planning + Design
Susan Hall, Lura Consulting

Re: **Road Classification**

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1 Introduction

This memorandum summarizes the assessment of the road classification system for the **City of Waterloo Transportation Master Plan (TMP) Update**. The report reviews the classification system and characteristics/criteria for the road network in Waterloo and proposes (re)classifications for City streets.

2 City of Waterloo Road Classification System

A street network performs most efficiently and effectively from both traffic operations and road safety perspectives if roads are planned, designed, operated and maintained to serve their intended purposes. This includes travel for all modes and the safety and convenience of all road users.

In keeping with this philosophy, a road classification system designates streets into different groups or classes according to the type of service (or function) each category is intended to provide. The 2011 TMP established a new road classification system for the City based on a people movement focus. The system remains relevant and is proposed to be carried forward as part of this TMP update with no changes to the existing road classifications and characteristics/criteria.

A new **Woonerf** classification is proposed based on the recommendations of the *Northdale Land Use and Community Improvement Plan Study – Urban Design and Built Form Guidelines*. A woonerf (Dutch for living garden), or shared street, integrates uses within the right-of-way removing the boundaries established in typical separated roadways between vehicles, cyclists, and pedestrians. Woonerfs are not intended to act as through streets and are expected to only serve adjacent uses. The intention is to integrate (not segregate) roadway users, and thereby increase safety by slowing down vehicular traffic. Larch Street in the Northdale neighbourhood is proposed as a Woonerf at this time. Other roads may be considered in the future.

With the addition of the Woonerf category to the existing designations, the classification system will comprise the following seven types of roads (in order from mobility to access):

- Provincial Highway (Ministry of Transportation responsibility)
- Regional Road (Region of Waterloo responsibility)
- City Arterial
- Major Collector
- Minor Collector
- Local
- Woonerf (new classification)
- Laneway (not shown on **Figure 1** due to scale)

Table 1 details the various characteristics/criteria that apply to each of the City's road classifications, describing the role of each category in the overall roadway network.

3 Proposed Road Classifications

Figure 1 shows the proposed classifications for the City of Waterloo road network based on the recommended road classification system detailed in **Table 1**. The figure identifies (in yellow highlight) the roads proposed for reclassification from their current designation shown on *Schedule 'E' – Road Classification System* of the City's Official Plan (Revision Date February 2018). The remaining roads would retain their current classifications per Schedule 'E'. **Table 2** summarizes the proposed changes, listing the specific roads/limits and their current (Official Plan) and proposed classifications.

The proposed Woonerf road category and reclassifications of specific streets would be incorporated into the City of Waterloo Official Plan by amendment.

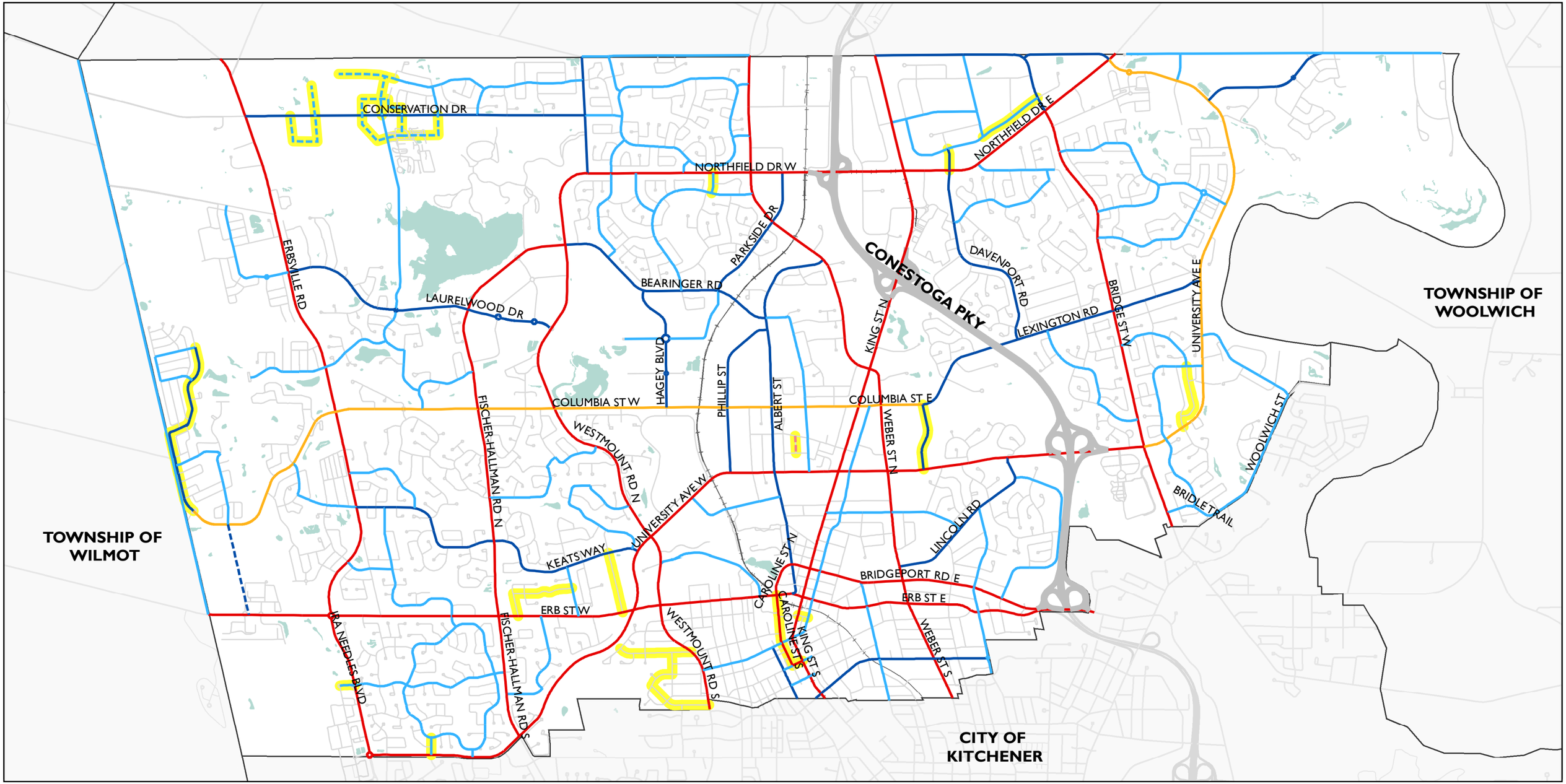

Figure 1.1
ROAD CLASSIFICATION

Map Version: 9/24/2019

Road Classifications

- Provincial Highway
- Regional Arterial
- City Arterial
- Major Collector
- Future Major Collector
- Minor Collector
- Future Minor Collector
- Future Woonerf
- Local Street

TMP Recommendation

- Recommended for Classification Change

0 1 2 KILOMETRES

THE CITY OF Waterloo

TRANSPORTATION MASTER PLAN

Table 1: City of Waterloo Roadway Classification Crtieria

Road Classification Characteristics	Road Classification					
	City Arterial	Major Collector	Minor Collector	Local	Woonerf	Laneways
ROW Width	30 – 35 m	20 – 30 m	18 – 20 m	16 – 18 m	10 – 13 m	6 m
Pavement Width	11 – 18 m	11 – 15 m	8 – 11 m	8 – 9 m	< 7 m	6 m
Vehicle Types	All Types, Truck Route	Residential: Passenger and Service Vehicles Industrial/Commercial: All Types	Residential: Passenger and Service Vehicles Industrial/Commercial: All Types	Residential: Passenger and Service Vehicles Industrial/Commercial: All Types	Residential: Passenger and Service Vehicles Industrial/Commercial: Restricted	Residential: Passenger and Service Vehicles Industrial/Commercial: Restricted
Innovation Potential	Opportunities for innovation to enhance person-carrying capacity and transit efficiency	Opportunities for innovation to accommodate non-motorized travel and reduce impacts of vehicular modes	Opportunities for innovation to accommodate non-motorized travel and reduce impacts of vehicular modes	Opportunities for innovation to develop safe and pedestrian friendly streets	Opportunities for innovation to develop safe and pedestrian oriented streets	Opportunities for innovations in the street orientation of buildings and to remove residential on-street parking
Streetscape Features	Opportunities for Basic and Enhanced Streetscape Features involving Furniture, Lighting, Trees and Landscaping	Opportunities for Basic and Enhanced Streetscape Features involving Furniture, Lighting, Trees and Landscaping	Opportunities for Primarily Basic Streetscape Features involving Boulevard Landscaping and Sidewalks	Opportunities for Primarily Basic Streetscape Features involving Boulevard Landscaping and Sidewalks	Opportunities for Basic and Enhanced Streetscape Features involving Furniture, Lighting, Trees and Landscaping	Limited to streetlighting and drainage opportunities in Laneways
Existing/Planned Adjacent Lane Use	Medium/High-Density Mixed-Use Development and Major Traffic Attractions	Mixed Land Uses in Range of Low/Medium Density	Primarily Low/Medium Density Development in Residential Neighbourhoods and Employment Areas	Primarily Low Density Residential Neighbourhoods and Employment Areas	Primarily Low/Medium Density Residential Neighbourhoods	Low Density Residential Neighbourhood with Frontages on Public Street
User Volume (Typical Motorized Traffic AADT)	12,000 – 30,000	< 12,000	< 5,000	< 2,000	Local Access Only	Local Access Only
User Volume (Pedestrian)	High	High	Medium	Low	High	Local Access Only with No Sidewalks
Design Speed	70 km/h Maximum	60 km/h	50 km/h	50 km/h	30 km/h Maximum	30 km/h Maximum
Average Running Speed	60 – 80 km/h	60 km/h	50 km/h	40 – 50 km/h	< 20 km/h	< 30 km/h
On-Street Parking Provisions	Generally Restricted	Generally Restricted	Permitted on One or Both Sides	Permitted on One or Both Sides	Permitted in Demarcated Spaces	Parking Generally Restricted on a Laneway
Land Service/Access	Primary Function is People and Goods Movement with Access Controls	Property Access and People and Goods Movement or Equal Importance	Property Access and People and Goods Movement or Equal Importance	Primary Function is to Access Individual Properties	Primary Function is to Access Individual Properties	Primary Function is to Access Parking Garages/Areas Located at Rear of Houses
Transit Service	Supports all Conventional and Rapid Transit Service	Conventional Transit Allowed	Conventional Transit Allowed	Generally Restricted	Restricted	Restricted
Pedestrian Facilities	Sidewalks on Both Sides	Sidewalks on Both Sides	Sidewalks on Both Sides	Sidewalks on Both Sides (City Sidewalk Policy, 2005)	Accommodate Safely Within Road Right-of-Way	No Sidewalks
Cyclist Facilities	Dedicated On-Road Facilities and Off-Road Facilities Where Appropriate	Generally Dedicated On-Road Facilities and Off-Road Facilities Where Appropriate	Accommodate Safely Within Road Right-of-Way	Accommodate Safely Within Road Right-of-Way	Accommodate Safely Within Woonerf Right-of-Way	Accommodate Safely Within Laneway Right-of-Way
Commercial Vehicle Access	Generally Allowed – May Be Subject to Time Restrictions	Permitted in Employment Areas or as Specified in Truck Route Bylaw	Permitted in Employment Areas or as Specified in Truck Route Bylaw	Not Permitted Except as Allowed in Employment Areas or Specified in Truck Route Bylaw	Not Permitted Except as Required by Adjacent Land Use	Not Permitted Except as Required by Adjacent Land Use
Maximum Intersection Separation	400 m	200 m	60 m	60 m	N/A	N/A
Maximum Intersection Pedestrian Crossing	400 m	200 m	60 m	60 m	N/A	N/A
Maximum Driveway Spacing	Generally Restricted			One Driveway per lot	N/A	N/A

Table 2: Proposed Road Classification Changes

Street Name	Limits	Current Classification	Proposed Classification
Alexandra Avenue	Lourdes Street to Westmount Road South	Minor Collector	Local
Allen Street West	Caroline Street West to King Street South	Minor Collector	Regional Arterial
Beaver Creek Meadows District Plan	Not Applicable	Not Applicable	Proposed Minor Collector
Caroline Street South	Allen Street West to Erb Street West	Major Collector	Regional Arterial
Churchill Street	Erb Street West to Amos Avenue	Minor Collector	Local
Dansbury Drive	Pastern Trail to Auburn Drive	Minor Collector	Local
Davenport Road	Northfield Drive East to Frobisher Drive	Minor Collector	Major Collector
Empire Street	Stanley Drive to Alexandra Avenue	Minor Collector	Local
Forsyth Drive	Stanley Drive to City Limit	Minor Collector	Local
Frobisher Drive	McMurray Road to Bridge Street West	Local	Minor Collector
Larch Street	Balsam Street to Hickory Street West	Local	Woonerf
Marsland Drive	University Avenue East to Columbia Street East	Local	Major Collector
Mcdougall Road	Erb Street West to Keats Way	Minor Collector	Local
Northgate Avenue	Glen Forest Boulevard to Northfield Drive West	Local	Minor Collector
Pastern Trail	University Avenue East to Dansbury Drive	Minor Collector	Local
Portsmouth Gate	University Avenue West to Westvale Drive	Local	Minor Collector
Stanley Drive	Forsyth Drive to Empire Street	Minor Collector	Local
Sundew Drive	Columbia Street West to Rock Elm Street	Minor Collector	Major Collector
Thorndale Drive	The Boardwalk to Ira Needles Boulevard	Not Applicable	Minor Collector
Willis Way	King Street South to Regina Street South	Minor Collector	Local

8 PROJECT VISION STATEMENT

Technical Memorandum

Date: April 29, 2020

To: Christopher Hodgson, City of Waterloo

From: Gene Chartier, Paradigm Transportation Solutions Limited

c.c.: Kate Whitfield, Alta Planning + Design
Susan Hall, Lura Consulting

Re: **Project Vision Statement**

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1 Introduction

This memorandum details the project vision for the **City of Waterloo Transportation Master Plan (TMP) Update**. The remainder of this report is organized as follows:

- Chapter 2 details the 2011 TMP vision and objectives;
- Chapter 3 summarizes the policy framework for the TMP Update; and
- Chapter 4 provides the proposed vision and goals for the TMP Update.

2 2011 TMP Vision

Section 2.1 of the 2011 TMP states the vision for the plan. The statement, which emanates from direction provided in the City of Waterloo's Strategic Plan 2007-2010, is as follows:

> ***To develop a coordinated and integrated transportation system that provides realistic alternative travel options to the auto thereby creating a City that is truly accessible to all.***

The vision is supported by the following principles from the Strategic Plan 2007-2010:

- Our Living Environment;
- Healthy and Safe Community;
- Economic Vitality; and
- Partnerships and Collaboration.

Since the 2011 TMP was adopted nine years ago, the City has implemented many of the report recommendations, citizens have elected a new City Council (twice) and the overarching planning policy framework has changed to reflect new direction from senior levels of government and the City's evolving strategic objectives. With this transformation, the City requires a more contemporary transportation vision that better reflects current priorities, future needs and emerging trends.

3 Policy Framework

The overarching land use and transportation planning policy framework plays an important role in guiding the direction and recommendations of the City's TMP. Policies enacted by all three levels of government (Province of Ontario, Region of Waterloo and City of Waterloo) help shape and support the transportation networks and services provided within a municipality and need to be reflected in the updated plan.

The **Planning Context** memorandum prepared during Phase 1 summarizes the plans and policies informing the TMP Update. Of those documents the 2019-2022 City of Waterloo Strategic Plan, City of Waterloo Official Plan and 2018 Regional Transportation Master Plan (RTMP) and have a significant (if not the most significant) influence on the plan vision and goals.

3.1 2019-2022 City of Waterloo Strategic Plan

The City of Waterloo Strategic Plan identifies the goals and priorities of the community over the 2019 to 2022 term of City Council. The plan also serves as a corporate strategy for the City, helping to guide how the municipality operates and delivers its services.

The Strategic Plan sets out the following vision for the City:

> ***Waterloo is an equitable community that leads the world in learning, discovery and caring.***

Building from the vision, the plan identifies the following six strategic pillars or areas of focus, which are guided by the principles of equity and inclusion, sustainability, fiscal responsibility, healthy and safe workplace, effective engagement, personal leadership and service excellence:

- Equity, inclusion, and a sense of belonging;
- Sustainability and the environment;
- Safe, sustainable transportation;
- Healthy community and resilient neighbourhoods;
- Infrastructure renewal; and
- Economic growth and development.

The Strategic Plan identifies **safe, sustainable transportation** as a strategic pillar. This condition "exists when all users and all modes of transportation are able to share roadways and trail systems safely; when traffic speeds respect the safety of the community; when policy and planning supports the development and maintenance of sustainable infrastructure; and when more residents are able to rely on sustainable modes of transportation such as public transit or active transportation to get where they need to go".[1] The end goal is to improve all modes of transportation thereby making Waterloo more mobile, accessible and connected.

With the Strategic Plan serving as the overarching policy and direction for the City, the strategy of safe, sustainable transportation needs to be captured in the TMP Update vision.

[1] City of Waterloo. https://www.waterloo.ca/en/government/strategic-plan.aspx

3.2 City of Waterloo Official Plan

The Official Plan is the City's long-range, comprehensive municipal planning document, providing a framework for land use decision-making in the City of Waterloo. The Plan sets a broad, coordinated vision for all lands within the City, and supports the overall goal of achieving a healthy community built on the principles of diversity and adaptability, accessibility and equity, connectivity, health and vitality.

Section 2.3 of the document identifies the following transportation objectives considered to have a significant influence on the land use policies and designations of the Plan:

- Encourage active transportation as an alternative to the automobile;
- Plan for and support a shift in focus from providing roads to move cars, to providing streets where people can interact and travel on, whether by foot, bicycle, transit or other motorized vehicle;
- Support and contribute to the success of the public transit system;
- Continue to provide bicycle and vehicular parking that meets community needs while balancing needs of motorists and active transportation users; and
- Plan for trails and open space networks and supporting facilities that are interconnected and service transportation functions.

Achieving a healthy and livable City and a transportation system that is sustainable into the future will require placing increased emphasis on moving people –managing travel in order to reduce reliance on the automobile in favour of transit and more active forms of movement such as walking and cycling. Chapter 6 of the Plan outlines the following key areas of focus when planning for the most efficient use of new and existing networks that support this transportation system vision:

- Ensuring compact, mixed-use land use patterns, providing people with the opportunity to live close to where they are working, learning, shopping and playing;
- Planning for a comprehensive, multi-modal, well-connected transportation system that offers safe and convenient alternatives to automobile travel;
- Planning for safe and convenient pedestrian and cyclist movement, giving priority to these travel modes in the planning, design and operation of the City's networks (road and trails/open space) as well as in the design of sites and buildings;
- Increasing the proportion of trips made by transit travel by planning for a more compact, mixed-use City form that supports a comprehensive and efficient transit system, including rapid transit; and
- Planning for the provision of appropriate bicycle and vehicular parking, balancing the desire for convenience with the desire to reduce automobile reliance.

With the Official Plan serving as the City's long-term planning guide for land use and development, the transportation system vision and key areas of focus need to be captured in the TMP Update vision and goals.

3.3 2018 RTMP

The 2018 RTMP sets the framework for the transportation network in the Region of Waterloo to the year 2041. To realize the vision set out in the plan, transportation goals and actions of the lower-tier municipalities, including the City of Waterloo, must align. The **Region of Waterloo Transportation Master Plan Summary** memorandum prepared during Phase 1 details the relevant policies influencing the TMP Update.

The vision statement for the 2018 RTMP is as follow:

Waterloo Region will be a prosperous, sustainable, and healthy community, with viable transportation choices for people of all ages and abilities, and for the goods supporting our economy.

The vision is supported by the following four goals and five broad strategies:

- Goals:
  - Promote Travel Choice
  - Foster a Strong Economy
  - Support Sustainable Development
  - Optimize the Transportation System
- Strategies:
  - Strategy 1 – Build a Transportation Network that Supports all Modes of Travel
  - Strategy 2 – Promote a Healthy Community
  - Strategy 3 – Develop a Frequent Transit Network
  - Strategy 4 – Enhance Inter-Regional Connections
  - Strategy 5 – Position the Region for Growth

The City of Waterloo plays a role in implementing Strategies 1 and 2, with responsibility for the road and active transportation networks under its jurisdiction. This important role should be reflected in the vision and goals for the TMP Update. The City also supports the Region in achieving Strategies 3, 4 and 5.

4 Proposed Vision Statement and Goals

Much has changed over the past nine years since City Council adopted the 2011 TMP. The recently released 2018 RTMP and 2019-2022 Strategic Plan focus not only on mode choice but also **equity, inclusion, sustainability, community health, safety, growth and prosperity.** Travel modes other than the auto will not just be considered “alternatives” but will represent viable transportation options for daily use. Residents and visitors to the City will have the option to travel safely and efficiently within and through Waterloo using their mode of choice regardless of age or abilities. Communities and transportation systems will be developed and maintained with sustainability and healthy living in mind. Existing resources will be used more efficiently or repurposed. A holistic approach to managing the transportation system will allow the City to continue to grow and prosper to 2041 and beyond.

With these objectives in mind, the proposed transportation vision for the updated TMP is as follows:

Waterloo has an equitable transportation system built on the principles of sustainability, choice and safety.

The vision is supported by the following four proposed goals:

- **Promote Travel Choice** – All individuals who live, work, visit or undertake recreational activities within the City can make trips in an integrated and seamless manner without having to drive (or own) a car. By achieving transportation equity, different travel modes, including walking, cycling, and public transit, are competitive in terms of travel time, cost, and accessibility.
- **Create a Sense of Belonging** – Transportation services provide access to equal opportunity and benefits for all citizens. Treating everyone equitably requires an acknowledgement of the unique circumstances different individuals face and provides the basis to eliminate systemic barriers. This helps to support overall neighbourhood livability, enhance quality of life and build a strong sense of community through primarily active transportation services.
- **Support Sustainable Development** – The transportation system supports sustainable growth initiatives within the City, benefiting both the economy and environment. Enabling sustainable development patterns helps to reduce transportation contributions to climate change.
- **Optimize the Transportation System** – Make the most of infrastructure and services that already exist. Managing transportation supply and demand will help to maximize the use of existing facilities and defer the need for new infrastructure that does not support the other goals.

9 COMPLETE STREETS REVIEW

TRANSPORTATION MASTER PLAN
LOOKING AHEAD

THE CITY OF Waterloo

alta PLANNING + DESIGN

Date: April 17th, 2020

To: Christopher Hodgson, City of Waterloo

From: Nataliya Pekar, Alta Planning + Design

Cc: Chris Dedman, City of Waterloo

Kate Whitfield, Alta Planning + Design

Gene Chartier, Paradigm Transportation Solutions Limited

Re: **City of Waterloo TMP – Complete Streets Review**

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1 Introduction

As part of its 2019 Transportation Master Plan (TMP), the City of Waterloo (City) is undergoing a review and update of its Complete Streets policy. The policy was adopted in the 2011 TMP[i] to direct planning, design, building, and operation of the roadway for all users and to recognize the health, social, environmental, and economic benefits of a multi-modal network. Advancing a Complete Streets framework remains a key focus for this TMP and is aligned with the overarching goal to achieve a network that is accessible and safe for users of all ages and abilities.

A strengthened Complete Streets policy is consistent with the direction of broader City and regional policies. At the regional level, the Growth Plan for the Greater Golden Horseshoe encourages municipalities to integrate pedestrians and bicycles into transportation planning. Similarly, the Provincial Policy Statement supports a focus on movement of people through safe, energy efficient, and multi-modal means and the Region of Waterloo TMP aims to build a transportation network that supports all modes of travel. The City of Waterloo Official Plan has strong support for Complete Streets integration with clear goals to achieve a healthy and livable City through a transportation system that reduces reliance on motor vehicles in favor of transit and active modes. The Official Plan emphasizes replacing the idea of roadways for moving vehicles with a vision for streets where people can interact and travel by foot, bicycle, and transit.

The transportation field has experienced rapid changes since the 2011 TMP. The following memo will review the present state of Complete Streets best practice, existing policies at the City, and policies in comparable municipalities in order to suggest recommendations that will frame a path forward for an improved approach in Waterloo. The memo also includes a benefits statement and review of potential impacts to capital, operating, and maintenance practices.

2 Background on Complete Streets

The following section will broadly define the Complete Streets approach and its evolution over time as well as provide resources for enacting Complete Streets policies in accordance with latest best practice.

What are Complete Streets?

Complete Streets is a broad policy approach but is typically defined as streets for everyone, purposely designed and operated to allow for safe access for all users. The Complete Streets vision is one of leveraging the potential for streets to support a variety of uses and a more diverse mode-share with focus areas of safety, health, multi-mobility, transit, accessibility, sustainability, and equity. For the City, Complete Streets policies are aimed to achieve the goal of being "economically viable, sustainable, vibrant, walkable, bicycle friendly, age friendly, accessible, and diverse"[ii].

While it is a high-level idea, a Complete Streets policy should translate to implementation strategies that alter regular decision-making in planning, design, construction, operation, and maintenance[iii]. More specifically, the National Complete Streets Coalition, a program of Smart Growth America, dispels several myths surrounding Complete Streets, noting that the approach is not a singular design element or prescription but context sensitive, not one special street project but a network approach, not a mandate for immediate retrofit but an incremental process with long term results, and finally, not a silver bullet but a strategy that requires actionable plans and resources[iv].

Complete Streets 2.0

The Complete Streets approach is not new, but is evolving in response to new transport modes, on-demand mobility services, and rapid integration of technology. The way people interact with streets is changing and cities are facing new uncertainty with regards to managing new mobility services and user expectations for efficiency and convenience. In this context, street design is increasingly complex and raises questions for designers, policy-makers, and the public on how to accommodate a growing list of modes and street uses while minimizing conflicts and achieving City goals.

Complete Streets 2.0 responds to this new reality, where the core principles remain the same, but the actions reflect a changing context for planning, design, maintenance, and operations. A variety of new ideas and design approaches are entering the transportation lexicon and being implemented in various jurisdictions. A sample of key emerging ideas are summarized below.

Mobility Hubs

Mobility hubs are central to Complete Streets 2.0 as a way to aggregate a growing number of modes while supporting economic and social uses. The goal of a mobility hub is to maximize choice, minimize distance, reduce conflicts, and provide amenities through smart use of constrained spaces and with tools such as curbside management and targeted use of technology[v]. Mobility hubs can look different, they can be linear along a block or in a concentrated site, but all recognize a diversity of users and prioritize inter-connection of modes. **Figure 1** shows a transit stop, the simplest example of a mobility hub. A transit stop of the future may incorporate parking for a variety of modes, dedicated space for ride-share and ride-hail pick-up and drop-off, separated cycling infrastructure, and real-time transit information.

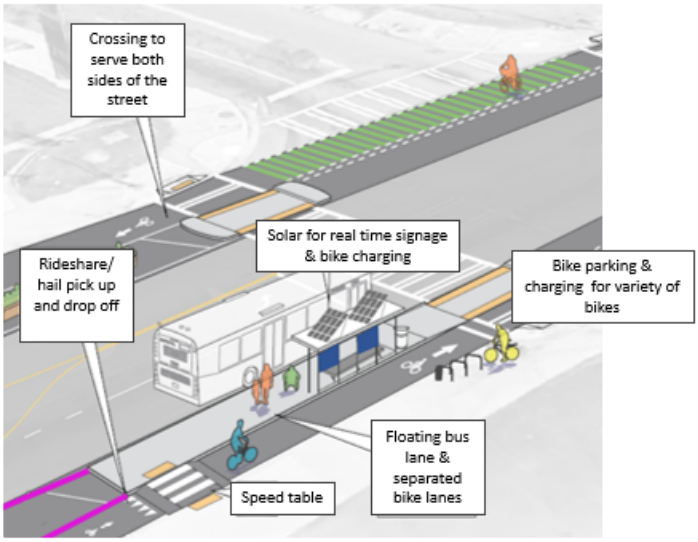


Figure 1: Bus Stop Mobility Hub

Curbside Management

Curbside management is a growing topic as cities work to accommodate a variety of competing uses vying for space in the street. Policies and practices will need to evolve to balance transit access, bikeway access, pedestrian access, traffic flow, and ride-sharing pick-up and drop-off in a way that is seamless and integrated. **Figure 2** visualizes a linear mobility hub with a variety of curbside uses. In Ontario, the City of Toronto adopted a curbside management strategy in 2017, recognizing that managing curb access is directly relevant to creating effective mobility and access along a corridor[vi].

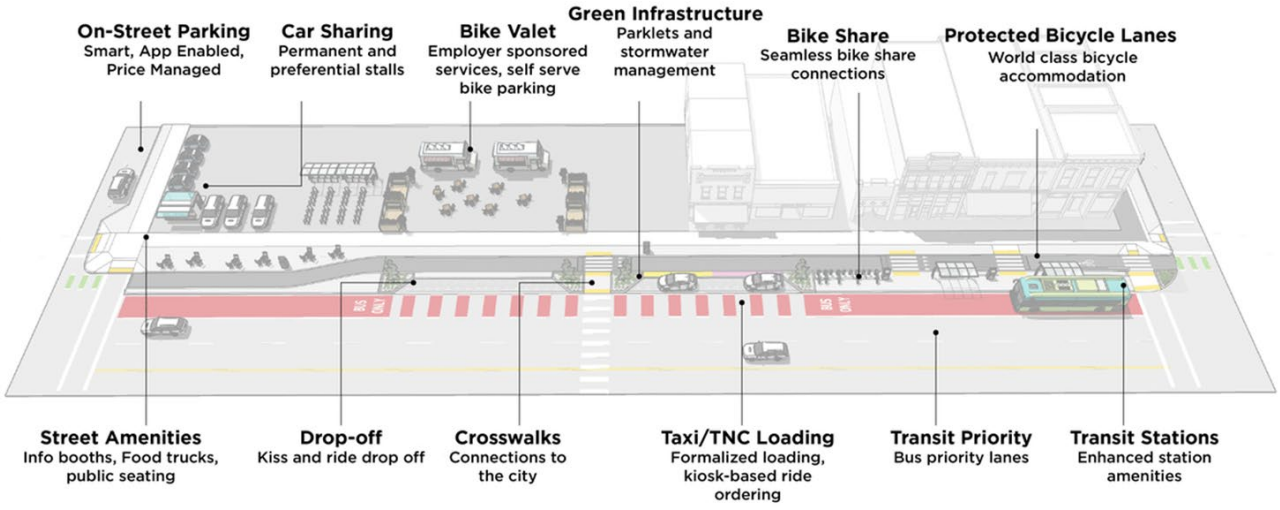


Figure 2: Complete Street 2.0 Mobility Hub (Source: NACTO)

Parking

Accommodation of parking needs is a consistent issue in planning and design. The City's Official Plan acknowledges this factor by seeking to provide parking that meets community needs while balancing the needs of motorists and active transportation users. A new approach to parking is ensuring streamlined access to space and reducing over-supply through planned contingency and overflow parking[vii]. As noted, parking needs to be provided to more than just motor vehicles, with supply of priority space for active and shared use mobility options such as transit, carshare, and bike share[viii]. Technology integration is also playing a role in parking management through navigation and payment apps and dynamic pricing mechanisms, particularly for on-street space.

Micromobility

The number of mobility options is growing. Currently, e-scooters and various forms of shared mobility are rising in popularity with the intention of targeting the short trips market. In Ontario, the provincial government recently launched a 5-year e-scooter pilot starting in 2020 which sets out rules for use and allows municipalities to pass by-laws allowing and regulating e-scooters on public roadways, including parks and trails[ix]. With the launch of the pilot, the province also released a best practices document to address key concerns of parking, operating parameters, safety, and liability[x]. The City has worked with micromobility options prior to the provincial launch, hosting its own pilot program in 2019 which allowed use on 7 km of trails, shown in **Figure 3**. Micromobility and e-micromobility offers opportunities to manage traffic congestion and contribute to economic development, but also presents challenges with regards to space allocation on sidewalks, bikeways, and trails. Cities will need tools for developing policies to manage micro-mobility while prioritizing safety and a vibrant public realm.

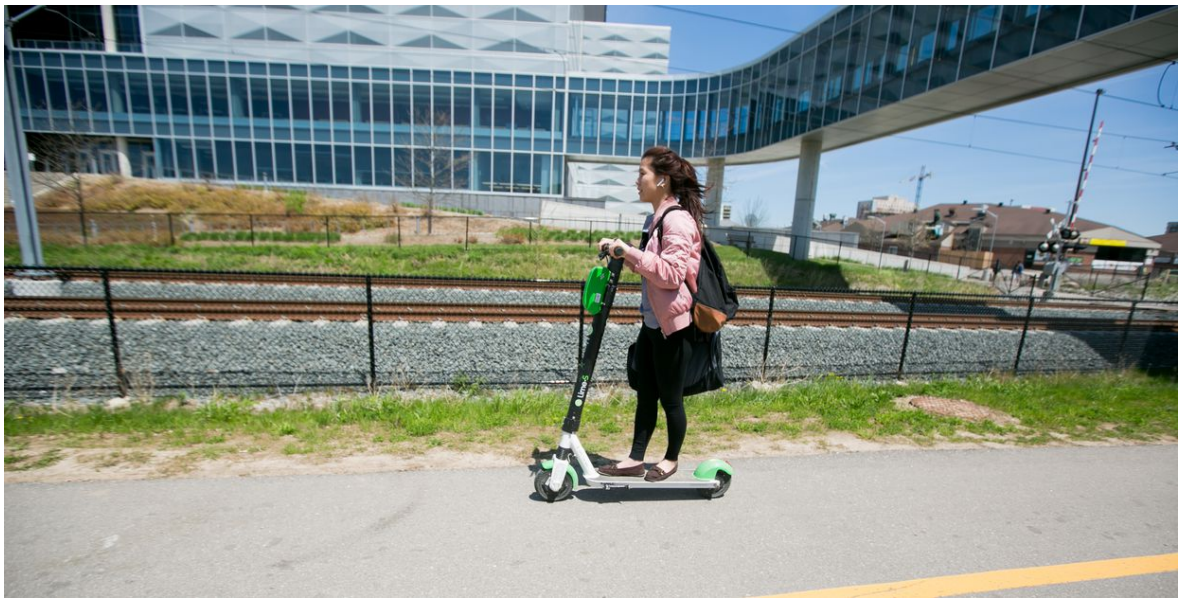


Figure 3: City of Waterloo Scooter Pilot[xi]

Best Practice Resources

Increasingly, communities are expecting their transportation departments to build roads that are safer and easier to access while accommodating a growing list of modes. There are a variety of resources available within the Complete Streets framework to achieve these goals.

Smart Growth America's Complete Streets Coalition offers a variety of resources from benefits fact-sheets, to cost-evaluations, to case-studies and implementation guidebooks. Their key resource is a guide with **Ten Elements of a Complete Streets Policy**, updated in 2018 and briefly summarized in **Table 4**. The resource details clear priorities and language for best practice in writing an effective Complete Streets Policy with an associated point system for evaluation[xii].

Complete Streets for Canada has a collection of resources specific to the Canadian context. The organization maps progression of Complete Streets work in Canadian regions and showcases projects. The organization has resources for Complete Streets evaluation, providing tools for understanding the performance of Complete Streets projects and policies[xiii].

The recently released 2017 Transportation Association of Canada (TAC) Geometric Design Guide for Canadian Roads includes references to Complete Streets principles[xiv]. TAC has also begun hosting Complete Streets webinars that provide guidance to planners and designers on creating multimodal streets and addressing key challenges[xv].

The Council TMP workshop held September 9th, 2019 emphasized the need to apply an equity and inclusion lens when implementing street projects in order to support vulnerable road users. By their nature, Complete Streets strive for equity, they are "planned, designed, operated, and maintained to be safe and comfortable for everyone regardless of age, ability, ethnicity, income, or chosen travel mode.[xvi]" However, centering equity in a Complete Streets project will look different depending on the scope, goals, and stage of the project. At the policy level, Smart Growth America provides resources for including equity in a Complete Streets framework[xvii]. At the planning level, centering equity can look like representative community engagement, or analysis of indicators for equity such as access, health, safety, and affordability for prioritization. A sample of this is described in the SFMTA Safe Streets Evaluation Handbook (2017)[xviii], a resource which includes a Demographic and Equity Analysis tool. At the design and implementation level, centering equity may look like design decision-making on road cross-sections, accessibility features, and amenities. A sample resource is Getting to the Curb (2019)[xix] by Walk San Francisco, a guide to building protected bike lanes that prioritize accessibility.

3 Existing Practice in the City of Waterloo

The City's 2011 TMP incorporated an overarching Complete Streets Policy for all streets to be planned, designed, operated and maintained to enable safe access for all users. The City of Waterloo was the second municipality in Canada to adopt a Complete Streets policy which was ultimately incorporated in the 2012 Official Plan[xx].

Through the Complete Streets framework, the 2011 TMP envisioned a city that is economically viable, sustainable, vibrant, walkable, bicycle friendly, age friendly, accessible, and diverse. To achieve this vision, the recommended policy:

- Incorporates Complete Streets into all transportation projects except where cyclists and pedestrians are prohibited by law, or there is a demonstrated absence of need, with exceptions provided and justified at the senior level

- Integrates Complete Streets with a complementary Linked Greenways or Trail Corridors Policy to support active transportation in non-street corridors
- Examines complementary policies for implementation within the short term, such as end-of-trip facilities, an advisory committee, trail and sidewalk maintenance in winter, on-road bikeway and trail implementation process that recognizes importance of network, parking policies, and intersection and traffic control policies

Four major pillars are identified for incorporating Complete Streets into all aspects of the City's responsibilities for streets. These pillars are planning and design, maintenance and operations, communications, and asset management, and are summarized in **Table 1** below. Implementation strategies were also included in the policy, focusing on restructuring City procedures and budgetary models, rewriting any City standards and guidelines, retraining staff, and creating a working group lead by a senior staff to oversee implementation, restructuring, and retraining.

Table 1: Complete Streets Policy – City of Waterloo, 2011 TMP Update

Category	Action Items
Planning and Design	• Planning of streets and street networks City-wide, in secondary plans and plans of subdivision • Design of street networks, corridors, intersections, site-specific improvements and traffic calming • Design of new construction, reconstruction, retrofit, and resurfacing roadway projects
Maintenance and Operations	• Maintenance of pedestrian and cyclist access and mobility through construction zones and in traffic management plans • Maintenance of streets for pedestrians and cyclist, including seasonal (debris, water, snow, and ice) and repair work (spot repairs, wear, deterioration, hazards)
Communications	• Public consultation and communications • Advisory committee responsibilities and function • Review of roadways within the City under Jurisdiction of MTO or RMOW • Collaboration with RMOW on Transportation Demand Management initiatives
Asset Management	• Audits of streets and alternatives for pedestrian and cyclists • Annual reviews of implementation of sidewalks, trails, and bikeway network • Establishment of performance standards and data collection procedures and analysis to benchmark how well streets are serving all users

In 2010, in the approach to the 2011 TMP update, two projects were completed that incorporated Complete Streets Strategies. These included road diets with capacity reductions and cycling infrastructure on Davenport Road and Bearinger Road. Since then, other projects have moved to consider active modes via reduced lane widths and inclusion of cycling infrastructure such as Columbia Street West (2017) with 1.8 metre raised bicycle lanes, and Lexington Road (2014) with 1.5 metre bicycle lanes and 0.7 metre buffers. Currently, the goals of the City remain consistent with Complete Streets policies. The city's Council has held discussions on safety and sustainability with the objective to shift mode-share away from vehicles. There is general consensus that the City cannot afford to widen roads and thus has a role to play in creating a transit-supportive environment with active transportation integration.

4 Review of Comparable Cities

The following section will review Complete Streets practices in two comparable mid-sized Canadian cities including the City of Ottawa and the City of London. A note has also been included on the City of Kitchener.

City of Ottawa

The City of Ottawa adopted a Complete Streets Policy in its 2013 TMP, following up with a Complete Streets Implementation Framework in 2015. The implementation framework defines Complete Streets policy as one that "incorporates the physical elements that allow a street to offer safety, comfort and mobility for all users of the street regardless of their age, ability, or mode of transportation. A Complete Streets approach uses every transportation project as a catalyst for improvements within the scope of that project to enable safe, comfortable and barrier-free access for all users"[xxi].

Policy Approach

The 2013 TMP incorporated Complete Streets through three action items:

- **"Adopt a Complete Streets policy for road design, operation and maintenance**: recognizing that Complete Streets do not result from "cookie cutter" design, considering context and recognizing that it is key to build a network as opposed to Complete Streets in isolation
- **Update road design guidelines, standards and processes to reflect Complete Streets principles** with a focus on new construction, renewal projects, and where high accident and safety issues remain prominent
- **Use multimodal levels of service** to assess road designs and allocate right-of-way

The policy represents a broad approach, but utilizes defined tools for implementation. For instance, to implement the action items, the City created a Complete Streets Advisory committee with representatives from several departments. The committee advanced an implementation framework as well as Multimodal Level of Service (MMLOS) guidelines.

The framework identified focus areas for implementation, specifically to:

- Provide staff with a foundation to implement policy by defining expectations for each project and coordinating inter-departmental communication
- Create an internal mechanism to address operational issues
- Implement early project scoping to align with the corporate asset management program and long-term budgeting, ensure context-sensitive solutions, and identify constraints early in the process including right-of-way ownership, major utility conflicts, and long-term maintainability
- Utilize MMLOS and target service levels for different modes rather than a prescribed design approach to evaluate options based on the location and context of the transportation project
- Align with Municipal Class Environmental Assessment Schedule
- Identify next steps: staff training, public communications, updates to existing policies, guidelines, standards, and documents, and monitoring

Implementation and Case Studies

The City of Ottawa has implemented Complete Streets on a variety of key projects and undergone a process of troubleshooting for common challenges. Some of these projects are summarized in **Table 2.**

Table 2: City of Ottawa Complete Streets Implementation

Project	Photo	Key Features and Lessons Learned
Churchill Avenue from Carling Ave to Princeton Ave (2014)		• Bundling of Complete Streets implementation with major rehabilitation and routine construction • Features: raised cycle tracks, improved street lighting, traffic control at three intersections, traffic calming, concrete curbs and sidewalks, streetscaping, utility relocation
Main Street (2016)		• Consideration of AODA with tactile separation of pedestrian and cycling right-of-way • Completed as part of an integrated road/sewer rehabilitation project

City of London

The City of London has been officially incorporating Complete Streets policies since 2013. The City identified a Complete Streets approach in its TMP and Urban Design Guidelines in 2013, following up with Complete Streets language in its 2016 Land Use Plan and finally developing a comprehensive Complete Streets Design Manual (CSDM) and complimentary Citizen's Guide to Complete Streets in 2018[xxii]. The CSDM is a more defined and prescriptive approach to implementing Complete Streets, identifying specific processes, tools, and metrics, but providing a larger set of resources.

Policy Approach

The CSDM defines Complete Streets as "those that are designed to support many different forms of mobility" and "provide physical environments that make all forms of mobility safe, attractive, comfortable, and efficient[xxiii]." The document builds on this definition with a set of key policy priorities, a vision, and five design principles. A key commitment in the vision is the goal that "all future construction, reconstruction, and rehabilitation projects for streets will be influenced by Complete Streets in planning and design." The policies are summarized below for reference:

- Strive for vision zero
- Create pedestrian friendly environments
- Consider all users and functions of a street
- Integrate Complete Streets design principles into decision-making process
- Coordinate built form decisions with transportation decisions
- Engage residents and stakeholders

After establishing a guiding framework, the CSDM identifies elements of a Complete Street (pedestrians, cyclists, transit, motor vehicles, green infrastructure, utilities, and municipal services) and provides options and design criteria for each element. These design recommendations are specific, with direction on design decisions such as clearway widths, types of cycling facilities, and transit stop configurations. The CSDM also provides tools to implement and evaluate Complete Streets through planning, conceptualizing, designing, implementing, and monitoring. The CSDM strives to monitor street performance, connectivity, vitality, safety, accessibility, and resilience and response to sustainability challenges. For planning, the guide applies street classifications in order to assist with the evaluation of trade-offs for decision-making based on intended character and function of a street and overall mobility goals. Street classifications were previously introduced in the 2016 City of London Official Plan. The guide dedicates a separate section for intersection design. Finally, implementation and monitoring are given a dedicated section which covers performance measurement and metrics.

A list of key tools in the CSDM is included for reference below:

- Workflow for developer-led files
- Monitoring and auditing tools
- Project scope tool to help identify appropriate project scale for a specific corridor
- Complete Streets checklist for designers and reviewers
- Stakeholder mapping tool
- Street element decision-making tool
- Street type priorities tool

Implementation and Case Studies

Because the City of London has recently passed the CSDM in August 2018, future work will determine the direction the City takes in implementing it. Currently, the City is undertaking two major projects with Complete Streets elements. The Downtown King Street Improvements project in 2019, from Ridout Street to Colborne Street, with before and after renderings pictured in **Figure 4** below, includes a new protected bike lane and buffer, on street-parking, designated loading zones, and new transit islands to reduce congestion on sidewalks[xxiv]. The City of London is also building its first flexible street under the Our Move Forward: London's Downtown Plan. It is described as a shared space by pedestrians, cyclists, and motorists with renderings shown in **Figure 5**[xxv]. The design includes a curbless cross-section, mid-block crossovers, and a maintenance program to set Dundas Street to the highest maintenance standard in the city[xxvi].

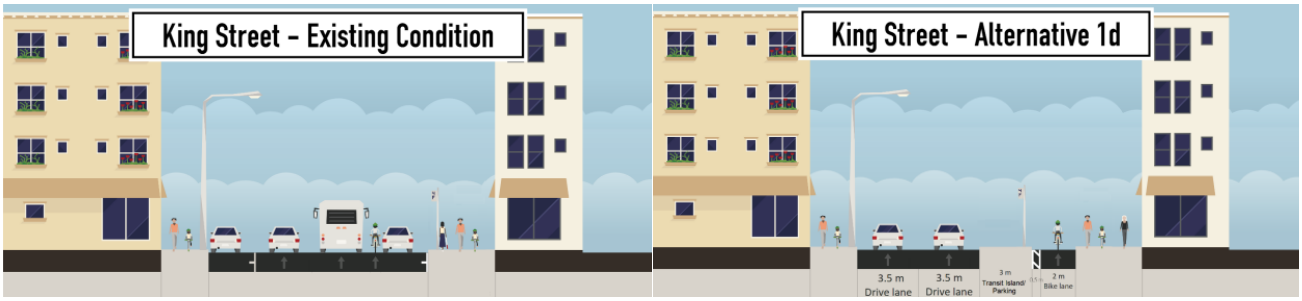


Figure 4: Downtown King Street Improvements Project[xxvii]

Figure 5: Dundas Place: London's First Flexible Street Renderings[xxviii]

A Note on the City of Kitchener

In 2019, the City of Kitchener released its Complete Streets guidelines with overarching goals to design for safety, improve transportation choices, and advance sustainability[xxix]. Kitchener defines Complete Streets as those that are "designed to be safe and comfortable for all, regardless of age or ability", a street that works well for pedestrians, cyclists, transit riders, motorists, and sustainable infrastructure. The City released both a comprehensive guideline document and a shorter community version. The document is to be used to guide all street projects in Kitchener, from new streets as part of development to re-construction projects and retrofits.

The guideline identifies possible interventions for streets based on their classifications, using score cards as a tool for evaluation, where each score card rates the level of service for various design categories (i.e. pedestrian, cycling, transit, motorist, sustainable infrastructure, and sense of place). The guideline also has a multi-level implementation and evaluation plan, with tasks to ensure Complete Streets policy and projects align with city strategies (official plan amendment, update development manual), enact tangible changes (conduct staff training, review warrant requirements), engage the community (pop-up workshops, community woonerf pilot), tie into street design (develop standard drawings, integrate transit design), and measure results (expand counting technologies, monitor maintenance and life-cycle impacts). Uniquely, the Kitchener guidelines recognizes emerging trends of mobility hubs, micromobility, and curbside management with the following tangible considerations:

- Mobility hubs
    - Minimize distance and follow desire lines
    - Reduce conflicts among travelers with smooth transitions where modes intersect
    - Provide amenities where waits are involved in transitions and consider making transition points function as community meeting places
    - Provide information on the streetscape to give people ways to understand options
- Curbside management
    - Create flexible spaces to encourage use in different ways according to the time of day or season
    - Provide designated delivery and ride-sharing drop-off locations
    - Manage parking pro-actively
- Micromobility
    - Pair stations with transit and leverage mobility options to fill first and last kilometer needs
    - Locate stations in high demand areas such as high employment, residential, and commercial
    - Protect the pedestrian realm to ensure storage does not interfere with the use of a street

5 Complete Streets Recommendations

The following section will set-up themes and ideas for recommendations on updates to the City's Complete Streets policies with emphasis on making improvements that strategically align with the vision for the City.

Incorporating Complete Streets 2.0

Complete Streets as an approach is changing to accommodate new transport modes, on-demand mobility services, and rapid integration of technology. A policy approach and corresponding set of tools will assist with achieving a defined vision for the City. Decision-making frameworks and tools that balance needs within the right-of-way should begin to incorporate Complete Streets 2.0 principles (**Figure 6**). These principles include prioritizing uses on the street, recognizing new modes, and incorporating flexibility. The City has already included some Complete Streets 2.0 principles, for example the provision of facilities such as parking, showers, and trip reduction incentives through the planning approvals process.

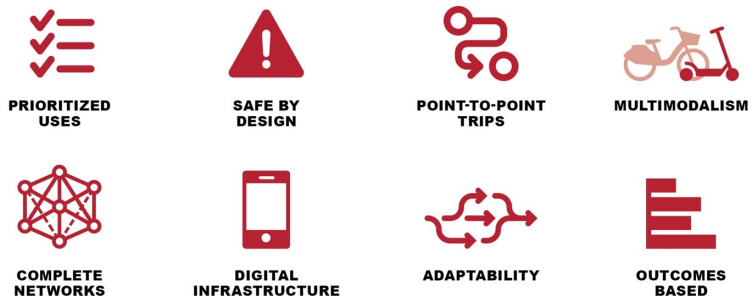


Figure 6: Complete Streets 2.0 Principles (Source: Alta Planning + Design)

New tools and policy approaches should prioritize:

- Allocating space to serve specific objectives defined by mode and demand while managing safety
    - Examples: Waterloo's first Woonerf street in the Northdale area, curb pricing, flex lanes, high capacity corridors, design by speed
- Measuring the right outcomes, for instance where person-throughput is prioritized over vehicle-throughput
    - Examples: both the City of London and City of Kitchener have developed tools to identify outcomes of policy and street design decisions, with the City of London creating monitoring tools for implemented projects
- Using interim treatments and pilot projects/demonstration projects as alternatives to major capital projects to test ideas and move forward on implementation
    - Example: City's e-scooter pilot, City of Kitchener goal to work with a community for a Woonerf
- Implementation of mobility hubs through policies and permitting to support shared-mobility services, bike parking, drop-off zones
    - Example: City of Kitchener goals to provide amenities where waits are involved in mode transitions
- Design for flexibility and changing uses in seasons or times of day

Tools for Implementation of Complete Streets

A comprehensive Complete Streets policy will identify and develop tools to address typical challenges that stall projects. In particular, tools help with managing trade-offs and design decision-making, particularly in constrained spaces. When properly built, processes and tools can be structured to ensure appropriate attention is paid to factors that may historically not receive due consideration, such as equity, green infrastructure, and street trees/urban forestry. The following list draws from the compared cities above for recommendations on potential tools:

- City of London: Toolkit in CDSM
    - **Project Scope Tool**: used to assist with identifying appropriate scale for a project from a full-design to minor interventions. It is to be used in the planning stage but brought back iteratively as more information is gathered on utility impacts and high-level feasibility assessment
    - **Complete Streets Checklist for Reviewers and Designers:** developed as a project management tool that guides projects through the steps of the guide, starting with conceptualizing what the corridor might looks like by selecting a context-appropriate cross-section and intersection design, then moving teams logically through core design, land-use, network, and user considerations and decisions on pedestrian, cycling, transit, motor vehicle, green infrastructure, and utility realms
    - **Street Element Decision-Making Tool:** a flow-chart that assists designers with identifying if a cross-section could be implemented within the right-of-way, and provides guidance on priorities and trade-offs to consider for when a preferred width outlined in the design manual is wider than the available right-of-way
    - **Street Type Priorities Tool (Figure 7):** an additional tool for evaluating trade-offs in instances of insufficient right-of-way width after use of the Street Element Decision-Making Tool, providing guidance in choosing elements to be included within the reality of a constrained space

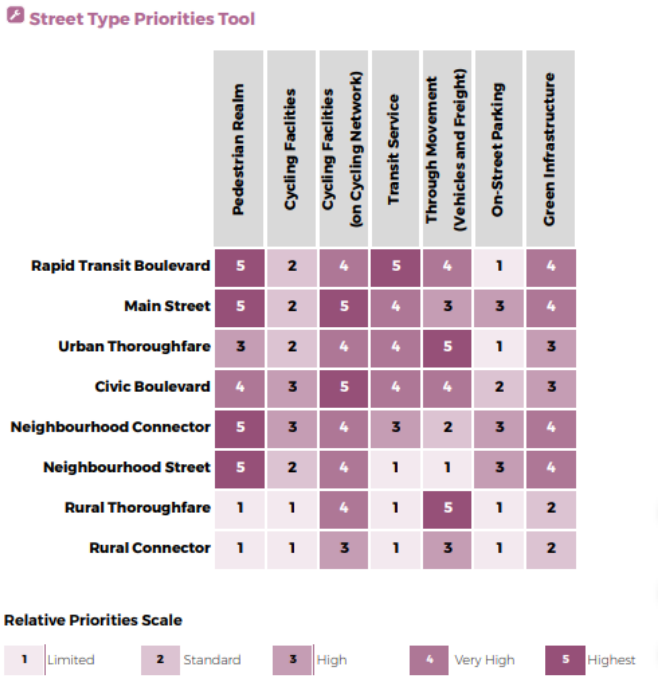


Figure 7: Street Type Priorities Tool from the London CSDM

- City of Kitchener: Score Cards
  - For implementation, decision-making, and trade-off evaluation when constraints arise, the City of Kitchener developed score cards to be used early in the design of any street re-construction project to leverage opportunities for making improvements
  - Score cards (**Figure 8**) are unique for every mode and street type (i.e. pedestrian, cycling, transit, motorist, sustainable infrastructure, and sense of place), and identify the level of service provided based on various characteristics of an existing or proposed facility. For example, a certain level of service consists of a specific minimum sidewalk width, distance between pedestrian crossings, boulevards space, average length of crossing, etc.
  - Score cards take a project team through a process of:
    - Assessing the "score" of the current state and identifying the challenges
    - Identifying opportunities to strengthen the score through a project
    - Completing an interim design and evaluating proposed upgrades by providing scores for options
    - Identifying capital and operating costs of proposed designs
    - Finalizing design by balancing resources while maximizing the score of the final street configuration

Local streets and minor collector streets criteria

PEDESTRIAN: What makes a street safe, comfortable and convenient for a pedestrian?

No level of service provided	Very poor level of service	Poor level of service	Acceptable level of service	Expected level of service	Exceeds expectations	Notes
0	1	2	3	4	5	Notes
No dedicated pedestrian facility is present	Facility on one side with minimum 1.5m width	Facility on one side with minmum 1.8m width	Facility on both sides with min 1.5m width	Facility on both sides with min 1.8m width	Sidewalk ≥ 1.8 m on both sides	
Curb face or less than 0.3m	0.3 m boulevard	0.3 - 0.5 m boulevard	0.6 - 0.9 m boulevard	1.0 -1.5 m boulevard	≥ 1.5 m boulevard	
Trees greater than every 40 m	Trees every 20 - 40 m on one or both sides of street	Trees every 11-20 m on one side of street	Trees every 11-20 m on both sides of street	Trees every 10 m on one side of street	Trees every 10 m on both sides of street	
Longest distance between pedestrian crossings > 300 m	Longest distance between pedestrian crossings 251 - 300 m	Longest distance between pedestrian crossings 201 - 250 m	Longest distance between pedestrian crossings 151 - 200 m	Longest distance between pedestrian crossings 101 - 150 m	Longest distance between pedestrian crossings < 100 m	Qualifying crossings: crosswalk, signalized crossing, PXO, curb extensions/raised crossing, refuge island
Average length of pedestrian crossings >10	Average length of pedestrian crossings 9.1 - 10 m	Average length of pedestrian crossings 8.1 - 9.0 m	Average length of pedestrian crossings 7.1 - 8.0 m	Average length of pedestrian crossings 6.0 - 7.0 m	Average length of pedestrian crossings <6 m	If refuge island present, use the longest leg for scoring

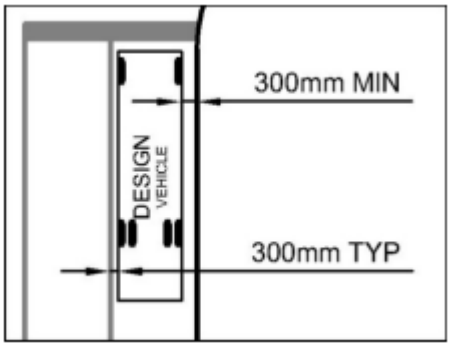
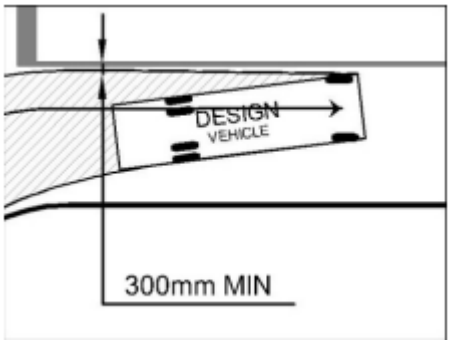
Figure 8: Pedestrian Score Card for Local and Minor Streets in the Kitchener CS Guide

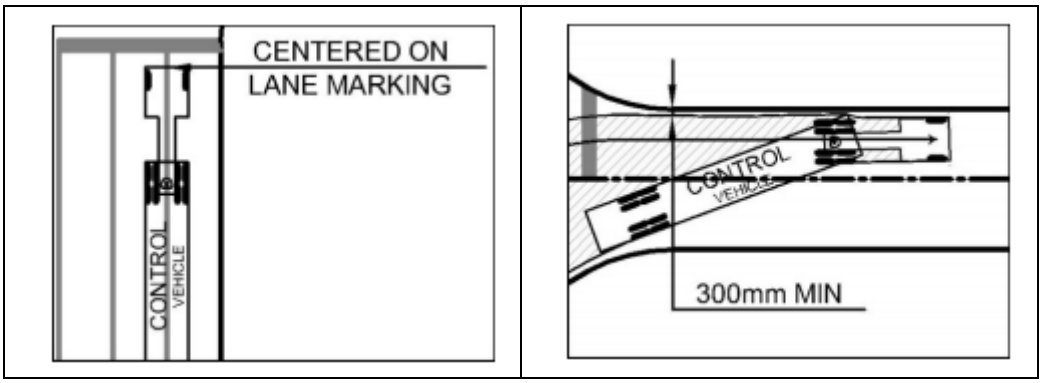
- City of Ottawa: MMLOS

- The City of Ottawa developed a MMLOS tool as a key component of incorporating Complete Streets into transportation planning processes through an update to the requirements for transportation impact assessment
- There are opportunities to learn from other cities such as Ottawa and the City of Halifax who primarily use it to assess applications for private developments through transportation impact assessment, as well as for their own municipal capital works projects

- City of Toronto: Curb Radii Guideline (Design and Control Vehicles)[xxx]
  - While not a city reviewed in this memo, the City of Toronto employs guidelines for curb radii design as a strategy for weighing trade-offs and allocating space in the right-of-way
  - The guideline details prescriptive and context-specific requirements for design and control vehicles when determining the size of curb-radii using turning envelopes – this is done with the goal to strategically accommodate vehicles while achieving safety and priority for vulnerable road users
  - Design vehicles are frequent users of a given street and are typically designed to turn using one incoming and one receiving lane
  - Control vehicles are infrequent users of a given street and are typically designed to turn using multiple lanes with allowance to encroach on oncoming lanes
  - The City of Toronto employs the strategy of design and control vehicles through the following specific measures:
    - Design and control vehicles are defined for each corner based on turning volumes of various vehicle types (derived from turning movement counts) and road classifications
    - Whether a vehicle is a design or a control vehicle, as well as the nature and classification of the street, determines the allowed turning maneuver (starting and ending position)
    - Further guidance is provided for constrained corners, with allowable ranges for parameters such as vehicle turning speed
    - **Table 3** shows an example of vehicle starting and ending positions for design and control vehicles depending on vehicle type, frequency of turn, and street type

Table 3: City of Toronto Curb Radii Guidelines Design and Control Vehicles

Design Vehicle – Starting Position	Design Vehicle – Ending (Arterial)
	
Occasional Large Truck Control Vehicle – Starting Position	Large Truck Control Vehicle – Ending Position (Arterial)



Complete Streets Policy Communications

Several municipalities have improved communication strategies to bring increase public engagement to Complete Streets implementation. Including additional communications tools corresponds directly to the communication pillar of the City's current Complete Streets policy.

The following are communications practices that can frame similar initiatives at the City:

- City of London's Citizen's Guide to Complete Streets
  - London's Citizen's Guide provides a concise overview of the processes and design elements that are covered in the CSDM
  - The guide is two pages, using one full page to define and visualize a Complete Street with an annotated graphic, and the second page to briefly explain the intent of the policy for the City of London
- City of Kitchener Community Guide to Complete Streets
  - Kitchener has opted to publish a separate community document for the purposes of communicating with the public on Complete Streets
  - This "community edition" is 20 pages long with a concise version of every section (the full guideline is 134 pages), but matches closely to that of the original document
  - The City of Kitchener intends to use score cards as a way to communicate with the public how decisions were made and why various components are prioritized for specific projects, including the types of benefits retrofits and changes will bring
- City of Ottawa MMLOS
  - The City of Ottawa includes MMLOS results on public open house boards as a way to communicate trade-offs and evaluation techniques when looking at various options

Strengthening Policy Framework

In order to align future Complete Streets policies with best practice, it is recommended to follow defined metrics created by the National Complete Streets Coalition of Smart Growth America as summarized in **Table 4**.

Table 4: National Complete Streets Coalition: Elements of a Complete Streets Policy[xxxi]

Element	Description of Model Policy and Metrics (Total 100 Points)
Vision and Intent	**Provides equitable vision for how and why communities want Complete Streets.** Points are allocated for: a clear intent with strong "shall" or "must" language; an indicated need to create a complete, connected network; at least one motivation for pursuing Complete Streets including equity; and specification of at least four modes.
Diverse users	**Benefits all users equitably, particularly vulnerable users.** Points are allocated for: language to prioritize vulnerable and underserved groups and creation of accountable and measurable definition for priority groups.
Commitment in all projects and phases	**Applies to new, retrofit/reconstruction, maintenance, and ongoing projects.** Points are allocated for: requirement for all new construction, retrofit, maintenance and ongoing operations to incorporate Complete Streets; and required accommodation of all modes during construction.
Clear, accountable expectations	**Makes any exceptions specific with a clear procedure that requires high-level approval and public notice.** Points are allocated for: inclusion of 1-2 exceptions but no more; clear indication of responsibility for granting exceptions; and requirement for public notice of exception.
Jurisdiction	**Requires interagency coordination.** Points are allocated for: requirement for compliance by private development projects; and intra-agency coordination.
Design	**Directs the use of the latest and best design criteria.** Points are allocated for: adoption of specific, best state-of-the-practice design guidance or requires development/revision of guides; and sets specific time frame.
Land use and context sensitivity	**Considers the surrounding community's current and expected land use and transportation needs.** Points are allocated for: requirement for new or revised land use policies, plans, zoning ordinances, etc.; consideration of community context; and identifies need to mitigate unintended consequences.
Performance measures	**Establishes performance standards that are specific, equitable, and public.** Points are allocated for: specific performance measures under multiple categories; specific implementation processes; embedding equity measures; requirement to release results publicly; assignment of responsibility to specific agency or group.
Project selection criteria	**Provides specific criteria for funding prioritization for implementation.** Points are allocated for: specific criteria to prioritize funding; and embedding equity.
Implementation steps	**Includes next steps for implementation of the policy with specific time frames.** Points are allocated for: revision of procedures, plans, regulations; requirement for workshops and staff training; assigns responsibility to new or existing committee with internal and external stakeholders; a strong community engagement plan.

6 Impacts on Capital, Maintenance, and Operating Practices

Complete Streets implementation varies depending on project context and scope. Because of a variety of different possible configurations, there is no one formula for impacts for capital, maintenance, and operating practices. However, consideration of impacts should be incorporated into long-term decision-making to align with the Long-Term Financial Plan and the Asset Management Plan, which seek to evaluate operating impacts of capital projects and new assets.

When evaluating Complete Streets, considering typical implementation of facilities such as cycling and pedestrian infrastructure can assist in evaluating the required investments and changes. For capital costs of active transportation implementation, please see the **Active Transportation Implementation Costs for Planning Cycling Projects** memo of this TMP. In general, Complete Streets projects can be stand-alone or bundled with major capital projects. Integration of Complete Streets policies into early scoping can reduce cost, particularly when added elements are coupled with major projects such as road resurfacing or reconstruction[xxxii]. Complete Streets policies can also yield new funding opportunities that can be leveraged for larger projects and investments.

For maintenance and operating impacts at large, **Table 5** identifies some examples of maintenance and operating considerations that may arise in implementation of Complete Streets policies.

Table 5: Maintenance and Operating Practices Associated with Complete Streets Implementation

Operation and Maintenance Practice	Consideration
Snow removal and winter maintenance	• Increased practices for priority snow clearing • Investment into equipment for active mobility infrastructure • Varying infrastructure requires different approaches
Greenery maintenance (shoulder plant trimming, tree and shrub trimming)	• Maintenance for new green spaces along facilities •
Culvert, gutter, and drainage grate inspection/repair	• Ensuring water pooling is mitigated around new facilities (ex. bikeways)
Pavement marking replacement	• Maintenance of visual separation
Inspections/auditing	• Ensuring new infrastructure (ex. bikeways) conditions are safe, elements and surface are satisfactory
Major damage response	• Ensuring safety of use for bikeways and sidewalks after major weather events or after incidents
Pavement sealing	• To provide flat, smooth surface and extend the roadway life

In addition, summarized below are noted practices and concerns expressed by City of Waterloo Operations staff at a meeting with Alta Planning + Design on March 6th, 2019:

- Existing practice to blow trails for 2 or 3 weeks in the spring
- Existing practice to deploy road sweepers in bike lanes once a month; a concern for bollard use
- Existing practice to top-up stone dust on trails

- Existing practice to mow 1 m strips on each side of trails
- Existing practice to do limb trimming in slow season
- Existing practice to do road line painting as part of a regular schedule
- Note: work with forestry for branches if encroaching onto roadway/paths of travel
- Note: concerns for bollard use due to clearance for road sweepers
- Note: stone dust is hard to manage in the winter
- Note: contractors are hired to do thermoplastic paint application, no maintenance plan currently exists

For more information on winter maintenance strategies and impacts of active transportation infrastructure, please reference the **Winter Maintenance for Active Transportation** memo of this TMP. The **Winter Maintenance for Active Transportation** memo also touches on topics of environmental impacts associated with de-icing and design considerations associated with snow storage.

Maintenance can also be considered in the design phase. The City of Kitchener identifies maintenance as imperative to ensuring a street is a Complete Street through all four seasons and identifies a list of maintenance and design directives for achieving this outcome. Examples of these directives include provision of boulevard space for snow storage, consideration of traffic calming elements impacts on snow removal, positioning of utility poles, gas mains, watermains/storm/sanitary sewers, and coordination for utility relocations early in the life of a project.

7 Benefits Statement

The Complete Streets framework ensures that the right-of-way is planned, designed, constructed, operated, and maintained to provide safe access for all users. Complete Streets provides benefits by improving safety, equity, health, transit, active transportation, while providing flexibility to evaluate trade-offs to reduce costs while enacting smart growth and building livable communities.

A strengthened Complete Streets policy aligns with the aims of the RFP and achieves goals identified in broader policy documents:

- Growth Plan for the Greater Golden Horseshoe
    - Encourages municipalities to integrate pedestrian and bicycle networks into transportation planning
    - Provincial Policy Statement
    - Supports transportation systems policies that focus on movement of people through safe and energy efficient systems
    - Promotes multi-modal transportation systems which include transit and active transportation
- Region of Waterloo TMP
    - Aims to build a transportation network that supports all modes of travel
- City of Waterloo Official Plan
    - Roads under the City's jurisdiction will be planned to serve as a network of complete streets, facilitating the movement of, and interaction between, all travel modes – pedestrians, bicycles, transit and motorized vehicles – within and throughout the City. The complete streets concept recognizes that the streets within the road network provide meeting places for social and business interaction and as such, need to provide access for a full range of citizens within the community
- City of Waterloo Strategic Plan
    - Includes guiding principles of sustainability and the environment, and safe, sustainable transportation
    - Encourages active transportation as an alternative to the automobile

- Shifts to providing streets where people can interact and travel by foot, bicycle, transit, etc.
- Aims to achieve a healthy and livable City with a transportation system that is sustainable into the future, requiring placing increased emphasis on moving people and managing travel to reduce reliance on the automobile in favor of transit and more active forms of movement

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[i] City of Waterloo, *Transportation Master Plan Final Report*. 2011. https://www.waterloo.ca/en/government/resources/Documents/Cityadministration/TransportationMasterPlan/Transportation-Master-Plan---PDF-Version.pdf

[ii] Ibid.

[iii] Transportation Association of Canada, *Complete Streets: Policy and Practice in Canada* (Ottawa: TAC, 2014). https://aqtr.com/system/files/file_manager/complete_streets_policy_and_practice_in_canada.pdf

[iv] Smart Growth America. "Introduction to Complete Streets" PowerPoint Presentation, Washington DC, March 2015. https://smartgrowthamerica.org/resources/introduction-to-complete-streets/?download=yes&key=46130645

[v] Alta Planning + Design. "CITE Complete Streets Workshop." PowerPoint Presentation, CITE, 2019.

[vi] City of Toronto, *Curbside Management Strategy: Improving How Curbside Space is Used*. 2017. https://www.toronto.ca/legdocs/mmis/2017/pw/bgrd/backgroundfile-109153.pdf

[vii] Alta Planning + Design. "CITE Complete Streets Workshop." PowerPoint Presentation, CITE, 2019.

[viii] Ibid.

[ix] Ministry of Transportation. "Ontario Announces E-Scooter Pilot to Help Grow Ontario's Economy." News Release, November 2019. https://news.ontario.ca/mto/en/2019/11/ontario-announces-e-scooter-pilot-to-help-grow-ontarios-economy.html

[x] Ministry of Transportation, *Best Practices Guide*. 2019. http://www.mto.gov.on.ca/english/vehicles/pdf/e-scooter-best-practices.pdf

[xi] Moore, Oliver. "The e-scooter invasion is coming to Canada. What will our cities to with them?" June 2nd, 2019. https://www.theglobeandmail.com/canada/toronto/article-the-e-scooter-invasion-is-coming-to-canada-what-will-our-cities-do/

[xii] Smart Growth America, National Complete Streets Coalition, *Elements of a Complete Streets Policy: Effective 2018* (Washington DC: 2018). https://smartgrowthamerica.org/app/uploads/2018/02/CS-Policy-Elements.pdf

[xiii] Dr. Ratkim Mitra, Dr. Paul M. Hess, Transportation Centre for Active Transportation, Clean Air Partnership, *Complete Streets Evaluation: Understanding Complete Streets in the Greater Golden Horseshoe* (2015). https://www.completestreetsforcanada.ca/wp-content/uploads/2019/01/Complete_Streets_Evaluation_19Mar2015.pdf

[xiv] Transportation Association of Canada. *Geometric Design Guide for Canadian Roads*. (2017)

[xv] Transportation Association of Canada. "Complete Streets: Key Challenges and Lessons Learned." https://www.tac-atc.ca/en/events-and-learning/webinars/complete-streets-key-challenges-and-lessons-learned

[xvi] Smart Growth America, National Complete Streets Coalition, *Complete Streets Mean Equitable Streets.* (Washington DC: 2016). https://smartgrowthamerica.org/app/uploads/2016/08/cs-equity.pdf

[xvii] Smart Growth America, National Complete Streets Coalition, *Elements of a Complete Streets Policy: Effective 2018* (Washington DC: 2018). https://smartgrowthamerica.org/app/uploads/2018/02/CS-Policy-Elements.pdf

[xviii] SFMTA. *Safe Streets Evaluation Handbook*. (2017).

[xix] San Francisco Vision Zero Coalition. *Getting to the Curb*. 2019. Online report: https://walksf.org/wp-content/uploads/2019/12/getting-to-the-curb-report-final-walk-sf-2019.pdf

[xx] City of Waterloo. *Official Plan*. 2018. https://www.waterloo.ca/en/government/resources/Documents/Cityadministration/Official-plan/Official-Plan-Consolidated-August-2018.pdf

[xxi] City of Ottawa, *Complete Streets Implementation Framework*. Simpson, Colin. Report 8, City of Ottawa: Transportation Committee, 2015. Online report: https://ottawa.ca/en/city-hall/planning-and-development/community-plans-and-design-guidelines/design-and-planning/completed-guidelines/complete-streets-ottawa

[xxii] Complete Streets for Canada. "London." https://www.completestreetsforcanada.ca/locations/london/

[xxiii] City of London, *London Complete Streets Design Manual*. 2018. https://www.london.ca/residents/Roads-Transportation/Transportation-Planning/Documents/CSDM%20-%2020181203%20-%20AODA%20Final.pdf

[xxiv] City of London, *Downtown King Street Cycling Improvements*. Scherr, Kelly. City of London: Civic Works Committee, 2018. Online report: https://pub-london.escribemeetings.com/filestream.ashx?DocumentId=50635

[xxv] City of London, "Design." Dundas Place. https://www.dundasplace.ca/design

[xxvi] City of London, "Dundas Place Environmental Assessment." http://www.london.ca/residents/Environment/EAs/Pages/My-Dundas-Place-Environmental-Assessment.aspx

[xxvii] City of London, *Downtown King Street Cycling Improvements*

[xxviii] City of London, "Design." Dundas Place
[xxix] City of Kitchener, *Complete Streets Kitchener*. 2019. https://www.kitchener.ca/en/resourcesGeneral/DSD-19-235-Complete-Streets-Guidelines-Kitchener.pdf
[xxx] City of Toronto, *Curb Radii Guideline*. June 2017. https://www.toronto.ca/wp-content/uploads/2017/11/9185-ecs-specs-roaddg-Curb_Radii_Guideline_Version_1.1_Jun2017.pdf
[xxxi] Smart Growth America, National Complete Streets Coalition, *Elements of a Complete Streets Policy: Effective 2018* (Washington DC: 2018). https://smartgrowthamerica.org/app/uploads/2018/02/CS-Policy-Elements.pdf

10 WIDTH OF VEHICLE TRAVEL LANES FOR URBAN STREETS

Date: January 21st, 2020

To: Christopher Hodgson, City of Waterloo

From: Matt Pinder, Alta Planning + Design

Cc: Kate Whitfield, Alta Planning + Design

Chris Dedman, City of Waterloo

Gene Chartier, Paradigm Transportation Solutions Limited

Re: **Waterloo TMP – Review of Best Practices Memo: Width of Vehicle Travel Lanes for Urban Streets**

1 Introduction

As part of its Transportation Master Plan (TMP) update, the City of Waterloo has conducted a review of lane widths for arterial, major collector, and minor collector streets. The configuration of lanes and their widths has a direct impact on various roadway characteristics such as distribution of vehicles types and modes, crossing distances, and parking availability. Decisions made regarding lane widths represent a conscious allocation of space that has implications for the use and function of a roadway. Altering lane widths can be a tool for effectively using limited right-of-way while achieving policy goals to prioritize safety for vulnerable users and design for all modes through Vision Zero and Complete Streets. This tool, coupled with an understanding of best practices and the relationship between lane widths, speed, capacity, and safety, can be used to design a road for all users, but also to fit its context within the overall network in the City of Waterloo.

This review evaluates how the City of Waterloo should design its cross-sections to align with broader policy direction and the goals of the TMP. The Provincial Policy Statement (PPS), Places to Grow Act and Growth Plan, Region of Waterloo Official Plan, Region of Waterloo TMP, and City of Waterloo Strategic Plan all reference investment in sustainable transportation, with a focus on multi-modal networks that integrate active transportation. In fact, the City of Waterloo Strategic Plan aims to give priority to pedestrian and cycling modes of travel in planning, design, and operation of roadways. With these policy directives in mind, this memo provides a review of lane widths through a summary of findings from existing design guidance, research, and best practices in comparable cities in Ontario. These findings are then used to provide recommendations, a set of alternative cross-sections, an analysis of potential impacts on capital, operating, and maintenance practices, and a benefits statement for the City of Waterloo context.

2 Research Review

The following section reviews the relationship between lane widths and speed, safety, and capacity by drawing on research and latest findings.

2.1 Relationship between Lane Width and Speed

Lanes wider than 3.2 metres may provide drivers with more margin for error, but they also tend to encourage drivers to travel at higher speeds[1]. Each additional 0.1 metre of lane width results in an increase in average travel speed of 1.5 km/h[2]. Expectedly, the travelled speed of the roadway also consistently decreases with reductions in lane width[3].

Speed has a relationship with both safety and perceived safety. For the former, it is widely accepted that speed is a key factor in collision severity, where higher operating speeds result in more severe crashes[4]. A recently published systematic review and meta-analysis found that the risk of pedestrian fatality increases with impact speed[5]. For the latter, findings suggest that increased speeds reduce comfort for pedestrians and cyclists[6]. By impacting speeds, lane widths play a role in creating safe conditions on a roadway.

2.2 Relationship between Lane Width and Safety

The relationship between lane width and the safety performance of a roadway varies significantly based on the context. On roadways with high speeds and low interruptions to traffic flow, such as rural highways and freeways, the *TAC Geometric Design Guideline for Canadian Roads (2017)* states that both safety and capacity increase with wider lanes, up to a width of 3.7 metres, with no additional improvement beyond 3.7 metres[7]. In urban and suburban environments, where speeds are typically 70 km/h or less and flow is frequently interrupted by traffic signals, narrower lane widths have no negative impact on safety performance[8]. Research has found that there is no evidence that crash frequencies increase on urban and suburban arterials where lane widths are reduced below 3.6 metres[9]. Finally, excessively wide lanes beyond 4.0 metres can have a detrimental impact to safety in all roadway environments. On congested urban routes, wide lanes may lead to confusion and improper lane use, while on rural roads they may encourage unsafe passing manoeuvres[10].

2.3 Relationship between Lane Width and Capacity

As with safety, the impact of lane widths on capacity is tied to roadway context. In urban and suburban environments, where speeds are typically 70 km/h or less and flow is frequently interrupted, narrower lane widths have been found to have no negative impact on capacity[11]. However, on roadways with high speeds and low interruptions, reductions in lane widths can lead to reductions in capacity[12].

3 Design Guidance Review

Four roadway design guidelines, each providing specific guidance on lane widths, were selected for review:

- *TAC Geometric Design Guideline for Canadian Roads (2017)*
- *MTO Design Supplement for TAC Geometric Design Guide for Canadian Roads (2017)*
- *NACTO Urban Street Design Guide (2013)*
- *AASHTO Green Book (2018)*

3.1 TAC Geometric Design Guideline for Canadian Roads (2017)

The recent 2017 update to the *TAC Geometric Design Guideline for Canadian Roads* (TAC GDGCR) represents a shift away from prescriptive design and towards a context-sensitive approach. The guide provides designers with a "design domain" for lane width selection, as well as supporting guidance. Designers are encouraged to make a context sensitive selection for the roadway based on a multitude of factors including service, cost, and safety. The guideline reinforces the need for evaluating trade-offs in the process, for instance to accommodate active modes.

The 2017 TAC GDGCR guidance for through lane width selection is separated into categories and summarized below. Additional guidance is provided separately for special purpose lanes and shoulders. It should be noted that the guidance excludes the width of the gutter when determining curb lane width and recommends a minimum offset of 0.25 metres when a gutter does not exist adjacent to a curb.

- **Inside lanes on a multi-lane roadway** should be between 3.0 to 3.7 metres. Where large vehicles must be accommodated, **curb lanes** should be at least 3.3 metres (TAC 4.2)
- For a **pedestrian-oriented roadway**, design should seek travel lanes in the 3.0 to 3.3 metre range. On a multi-lane roadway, this translates to 3.3 metre curb lanes and 3.0 metre inside lanes (TAC 6.6.1)
- **Wide curb lanes** are offered as a cycling-supportive design feature, allowing side-by-side operation of cyclists and motorists when lanes are 4.3 to 4.9 metres wide. It is noted in the guidance that this lane configuration can result in higher motor vehicle travel speeds and higher use by heavy vehicles, both of which deteriorate the quality of the cycling environment. It is also noted that regardless of width and design, many cyclists are simply not comfortable riding in a mixed environment (TAC 5.3.2.3)

3.2 MTO Design Supplement for TAC Geometric Design Guide for Canadian Roads (2017)

The Ministry of Transportation of Ontario (MTO) design supplement to the TAC GDGCR was published in 2017 with the intent of providing specific guidance for Ontario highways. It replaces many sections of the TAC GDGCR, including the guidance on lane width selection. The supplement focuses primarily on provincial highways and its applicability and detail for urban contexts is more limited. However, while it is more prescriptive, the design supplement does follow similar principles to other guidelines included in this review, particularly in that higher speeds and truck volumes on major highways warrant wider lanes, whereas narrow lanes are appropriate in lower volume and more local contexts.

The supplement does not provide information on lane widths and their relationship to travel speed or safety, but does state that the capacity of an undivided highway is markedly affected by lane width, with reductions

in lane width leading to reductions in capacity. The supplement also states that capacity is reduced by narrow shoulders or lateral obstructions less than 2.0 metres from the edge of pavement.

The MTO design supplement is more prescriptive than the TAC GDGCR, offering specific guidance based on speed, AADT, and DHV. It should be noted that all widths provided are in addition to a curb which includes a 0.4 metre gutter.

- For **four-lane divided urban roadways,** lane width is determined solely by design speed. For design speeds of less than 80 km/h, recommended lane width is 3.5 metres, and for 80 km/h or greater, 3.75 metres is recommended
- **Undivided urban roadways:** the recommended lane width is a function of design speed and AADT, as seen in **Table 1** below

Table 1 - MTO Lane Width Guidance for Undivided Urban Roadways

Design Speed	AADT	Recommended Lane Width
40-50 km/h	<1000	2.75-3.0 m
50 km/h	1,000 to 3,000	3.0 m
60-70 km/h	1,000 to 3,000	3.25 m
	3,000 +	3.5 m
80 km/h	3,000 +	3.5 to 3.75 m

3.3 NACTO Urban Street Design Guide

The *NACTO Urban Street Design Guide* was created to support roadway design in urban environments to promote streets that are safer, more livable, and more economically vibrant. It provides guidance on lane width selection with the goal of balancing traffic calming and accommodation of larger vehicles, such as trucks and buses. Similar to other guidelines, NACTO recognizes a variety of contexts, for instance that major truck routes might require wider lanes.

The guide asserts that narrower lanes promote slower driving speeds which can reduce the severity of crashes. When narrower lanes lead to narrower streets, the result is reduced crossing distances for pedestrians, shorter signal cycles, less stormwater runoff, and lower roadway construction costs. Lane width guidance in the *NACTO Urban Street Design Guide* is summarized below. The guide does not include specific guidance for measurement of lane widths. The provided widths are likely measured from the centre of lane line with considerations for curb and gutter left to context and local preference.

- Lane widths of 10 feet (3.05 metres) are appropriate in **urban areas**, and have a positive impact on safety without impacting traffic operations
- **Wider curb lanes** of 11 feet (3.35 metres) may be used as a width for an outside lane to support truck or transit vehicle traffic
- Lanes greater than 11 feet (3.35 metres) should not be used as they may result in speeding and make poor use of right-of-way that could be allocated to other modes
- Parking lane widths of 7-9 ft (2.1 to 2.7 metres) are generally recommended, with the suggestion to demarcate parking lanes to indicate to drivers how close they are to parked cars. In certain cases, with loading and double parking, wide parking lanes up to 15 ft (4.5 metres) may be used

3.4 AASHTO Green Book, 7th Edition

The *AASHTO Green Book* provides design guidance on current highway and street design research and practices. The latest edition of this guide, released in 2018, encourages flexible design and acknowledges that in some cases, previous policy may have led to overdesign of roadways, resulting in construction projects that were more costly than necessary or were inappropriate for the roadway context.

The *AASHTO Green Book* identifies advantages to constructing narrow lanes, including space for more lanes (such as bicycle lanes), lower operating speeds, shorter pedestrian crossing distances, reduced construction costs, and less stormwater runoff. The guide also states that within interrupted-flow operating conditions at speeds less than 70 km/h, narrow lane widths are normally adequate and produce some advantages.

Below is a summary of specific guidance provided for lane width selection. The guideline treats curb and gutter with specific criteria. A gutter of contrasting color and texture should not be considered part of the traveled way, while a gutter with the same surface color and texture, and which is not much steeper in cross slope, may be considered part of the traveled way – a technique that the guideline recognizes is used frequently in urban contexts. The guidance states that curbs reduce effective through-lane width, with a note that while in urban contexts curbs may be placed at the edge of the traveled way, it is preferable that curbs be offset 1 to 2 ft (0.3 to 0.6 m).

- Roadway lane widths are recommended as a range of values, from 2.7 metres to 3.6 metres
- **For urban arterials**, lane widths may vary from 3.0 metres to 3.6 metres:
    - 3.0 metre lanes may be used where truck and bus volumes are relatively low and speeds are less than 60 km/h
    - 3.3 metre lanes are used extensively
    - 3.6 metre lanes may be used on high-speed, free-flowing principal arterials

4 Review of Comparable Cities

Three Canadian cities, comparable to the City of Waterloo, were selected for review on the basis of proximity and climate:

- City of Ottawa – lane width guidance partially updated in 2017
- City of Toronto – lane width guidance updated in 2017
- City of London – lane width guidance included in the 2018 *Complete Streets Design Guide*

4.1 City of Ottawa

The City of Ottawa publishes standard cross-sections for the design of its roadways, including lane widths, in the 2008 *Road Corridor Planning and Design Guidelines*. As part of its ongoing study, *Building Better and Smarter Suburbs* (BBSS), the City also approved new standard cross-sections for arterial roadways in 2017. Both documents provide standard lane widths for roadways based on their classifications.

Notably, the 2017 update to Ottawa's guidance for arterial roadways resulted in a decrease in the recommended lane widths, from a 3.5 metre curb lane and 3.75 metre through lane, to a 3.5 metre curb lane and a 3.25 metre through lane. The City of Ottawa's guidance update also removed the centre median from Ottawa's standard arterial cross-sections in order to reduce the overall crossing distance for pedestrians by 30%, as shown in **Figure 1** and **Figure 2**. This change reduces pedestrian exposure to traffic, allowing for

shorter pedestrian crossing phases. The change also results in a shift to providing snow storage in a boulevard adjacent to the curb lane, rather than in a centre median. Significant annual snowfall is a particular concern for the City of Ottawa and this is reflected in the guidelines through provision for storage in the form of 2.0 to 3.0 metres of boulevard space along the roadway edge where possible.

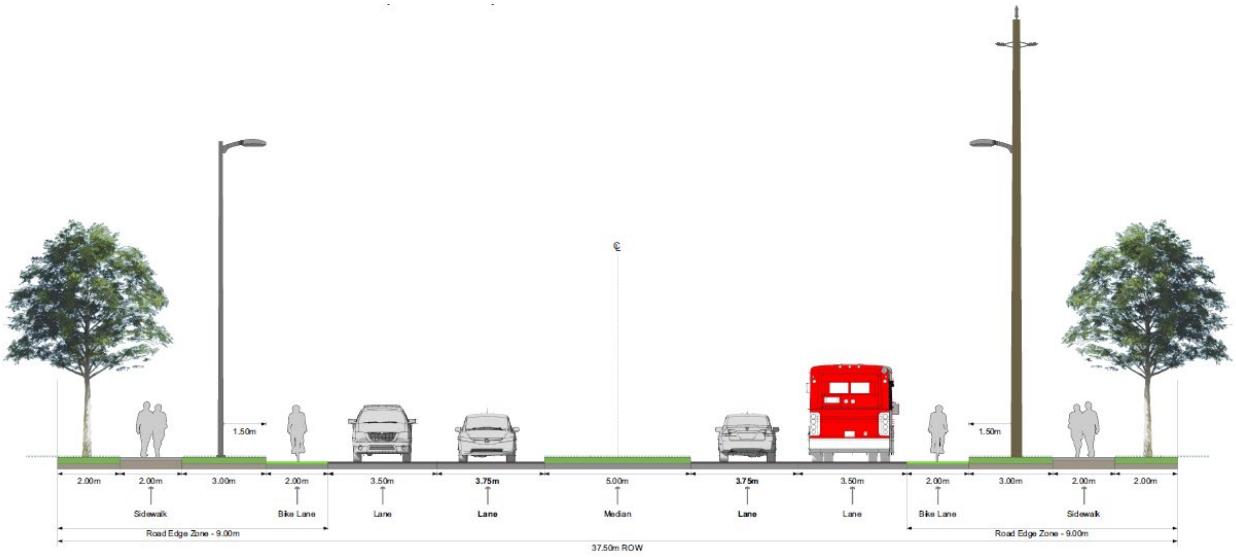


Figure 1 – City of Ottawa's Former Arterial Road Cross-section

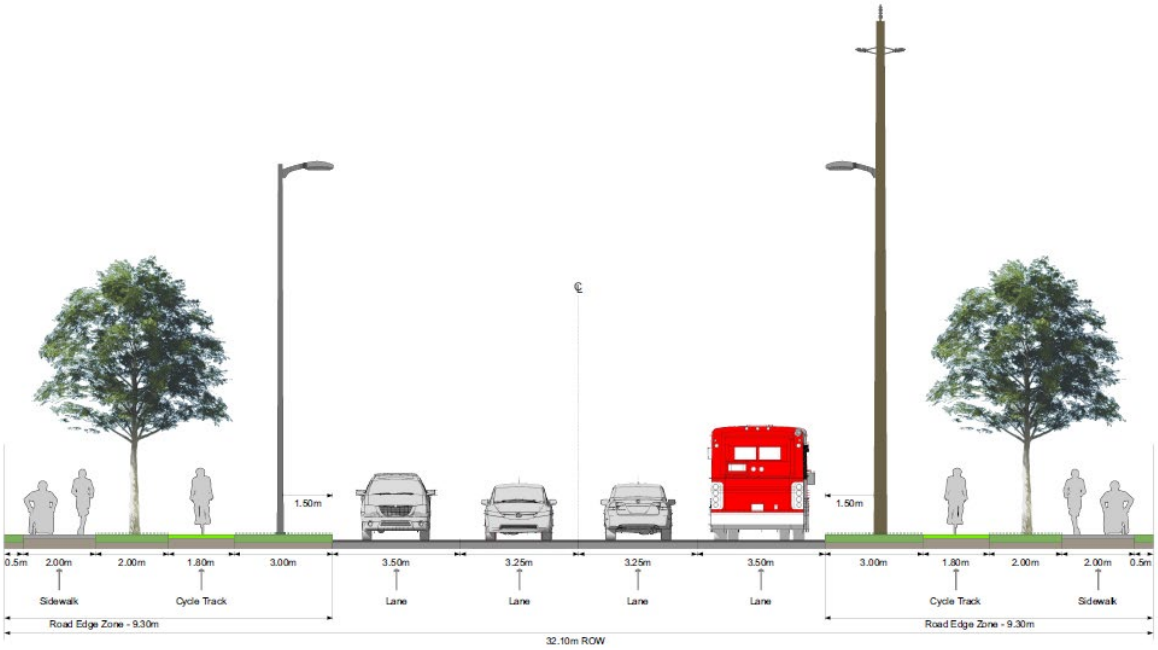


Figure 2 - One of the Versions of City of Ottawa's Updated Arterial Cross-sections

Ottawa's lane width guidance for two-lane collector roads is published in its *Road Corridor Planning & Design Guidelines* (2008). It is summarized below.

- 3.5 metres for a cross-section with on-street parking lanes (2.25 metre parking lanes in neighbourhoods and 2.5 metres in commercial areas)
- 3.25 metres for a cross-section with 1.5 metre on-street bicycle lanes
- 4.25 metres for a cross-section in mixed use centres where on-road cycling and road-edge drainage facilities are desired (a "shared lane") with on-street parking lanes (2.25 metres)

A review of the City of Ottawa's collector road cross-sections is underway as part of the BBSS program, which has outlined a need for local and collector streets with reduced vehicle lane widths and traffic calming measures[13]. The public engagement for this study also found that requirements for on-street parking on streets with low on-street demand results in wider streets than necessary, which encourages speeding[14].

4.2 City of Toronto

The City of Toronto released its *Toronto Lane Widths Guideline* document in 2017 with a clear focus on using lane widths as a tool to manage speeding. The guideline states that "wide lanes allow for and encourage vehicles to travel at excessively high speeds" and that "implementing lane widths that are not excessively wide encourages drivers to travel slower and not exceed the speed limit resulting in reduced impact speed in the event of a collision and [providing] drivers with more reaction time."

The *Toronto Lane Widths Guideline* is the only municipal standard reviewed that recommends lane widths based on the posted speed of the roadway, rather than its classification. A minimum, target, and maximum width are established for both curb and through lanes on roadways with a posted speed of 40 km/h or less, 50 km/h, and 60 km/h or more. Additional considerations are given for transit routes, trucking routes, and through horizontal curves. The guideline accommodates cycling on every roadway, either through a shared curb lane (target 4.3 metres), an urban shoulder (target 2.3 metres), or a dedicated cycling facility (varies). Urban shoulders are also used for snow storage and on-street parking.

The target widths are summarized in **Table 2**. The guideline states that curb lane widths are measured from the centre of the paint line to the edge of the curb. Notably, the City of Toronto's guideline recommends 3.0 metres for through lanes in all contexts and only recommends wider 3.5 metre curb lanes on roadways posted at 60 km/h or more.

Table 2 - Summary of Target Lane Width Guidance from City of Toronto

	Roadway Posted Speed (km/h)		
	40 or less	50	60 or more
Through Lane	3.0 m	3.0 m	3.0 m
Curb Lane	3.3 m	3.3 m	3.5 m
Shared Curb Lane	4.3 m	4.3 m	4.3 m

4.3 City of London

In August 2018, the City of London released its *London Complete Streets Design Manual*, which aims to promote the design and upgrading of London's streets to support a wider range of users. The manual categorizes roads based on their intended function, and the urban road categories include Rapid Transit Boulevard, Urban Thoroughfare, Civic Boulevard, Main Street, Neighbourhood Connector (shown in **Figure 3**), and Neighbourhood Street. It is assumed that the first four of these roadway types perform a higher-order function and can be classified as arterial roadways, while Neighbourhood Connector streets function as collector roadways.

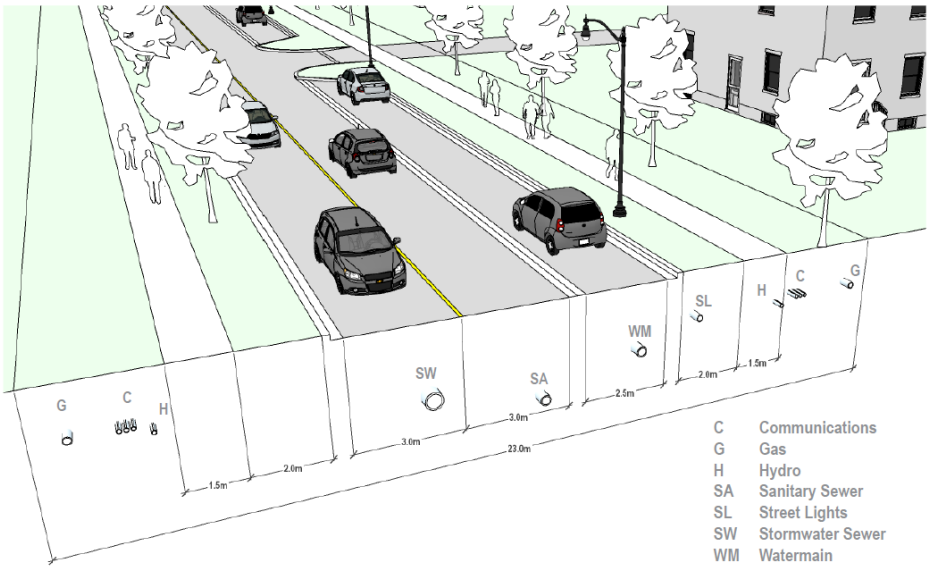


Figure 3 – Cross-section of a Neighbourhood Connector Street from the London Complete Streets Design Manual

The manual recommends that snow storage be accommodated in a landscaped strip adjacent to the roadway, which should be a minimum of 1.0 metre wide.

The manual provides the following guidance for lane width selection (excluding the gutter width):

- For **Arterial streets**:
  - 3.5 metres for a curb lane where the design vehicle is a truck or a bus
  - 3.3 to 3.5 metres for an inner lane of a street with multiple lanes
- For **Collector streets**, the recommended lane width is 3.0 metres

5 City of Waterloo Current Practice

The City of Waterloo's engineering manual provides standard cross-sections for various roadway configurations including city arterial, major collector, minor collector, and local roads. The current cross-sections were published in 2005 and the manual is presently under review.

The current cross-section standard lane widths as provided are:

- Two-lane road, no median: 3.7 metre lanes, 1.5 metre bike lane
- Two-lane road with 3.0 metre median: 4.2 metre lanes, 1.5 metre bike lane
- Four-lane road with 5.0 metre median: 3.65 metre lanes, 1.5 metre bike lane

A number of recent road reconstruction projects by the City of Waterloo have deviated from these standards to be more suitable with the context of the roadway. These include:

- **Columbia Street West (Fischer-Hallman Road to Erbsville Road), Arterial Road, constructed 2017:** four-lane arterial roadway with 4.20 metre median, 3.35 metre lanes, and 1.80 metre raised bicycle lanes
- **Davenport Road (Northfield Drive to Lexington Road), Major Collector, constructed 2010:** two-lane roadway with 4.5 metre median, 3.25 metre lanes, and 1.50 metre bicycle lanes
- **Lexington Road (University Avenue to Davenport Road), Major Collector, constructed 2014:** two-lane roadway with a 2.9 metre median (mix of concrete islands and painted median), 3.25 metre lanes, and 1.5 metre bicycle lanes with a 0.7 metre painted buffer
- **Bearinger Road (Westmount Road to Albert Street), Major Collector:** two-lane roadway with median and median refuge islands (vary), travel lanes 3.25m, bike lanes 1.5m
- **Keats Way (University Avenue to Erbsville Road), Major Collector:** two-lane roadway with median and median refuge islands (vary), travel lanes 3.25m, bike lanes 1.5m

All of these projects have used notably lesser lane widths than shown in the City of Waterloo's standard cross-sections, using lane widths as narrow as 3.25 metres on a major collector roadway.

6 Summary and Recommendation

The following section summarizes findings from the review of research, design guidance, and policies of comparable cities and provides recommendations for the City of Waterloo.

6.1 Summary of Findings

Changing lane widths as a tool in design can have a direct impact on other key roadway characteristics. **Section 2** investigated the relationship between lane widths and speed, safety, and capacity. The general findings within an urban context are that wider lanes result in higher speeds which produce higher collision severity, reduced safety, and less comfort amongst cyclists and pedestrians. In environments where speeds are below 70 km/h and flow is frequently interrupted, narrow lane widths have not been found to negatively impact safety performance nor have significant implications for capacity.

The findings described above are reflected throughout the design guidance reviewed in **Section 3**. The TAC GDGCR, *NACTO Urban Street Design Guide*, and *AASHTO Green Book* recognize benefits in efforts to reduce lane widths. The TAC GDGCR recommends a range of 3.0 to 3.7 metre, with 3.0 to 3.3 metre for pedestrian oriented roadways. The *NACTO Urban Street Design Guide* recommends 3.05 metres in urban areas, 3.35 metre curb lanes to accommodate trucks, and urging against larger than 3.35 metre lanes as a poor use of right-of-way and potential encouragement of speeding. The *AASHTO Green Book*, similarly to TAC GDGCR, suggests a range of 3.0 to 3.6 metre for urban arterials with reductions for low speed environments. The MTO TAC design supplement is more prescriptive and focuses more prominently on provincial highways, preferring larger lanes for higher speeds and volumes on undivided urban roadways with 3.5 metres for 3000+ AADT and

60-70 km/hr. However, the MTO TAC design supplement also allows narrower lanes for lower volumes and speeds.

Recently released guidance in all three comparison cities include reduced lane widths. This direction is consistent with design guidance and research findings, with goals to capture benefits for safety, speed reduction, and accommodation of a larger variety of road users. The City of Ottawa reduced it's recommended lane widths, shifting from 3.75 to 3.25 metres for its curb lane. The City of Toronto adopted 3.0 metre for through lanes and 3.3 to 3.5 metre for curb lanes, providing ranges to include large vehicles and varying contexts. Finally, the City of London, in its *Complete Streets Design Manual*, has suggested 3.0 metre for collector streets and 3.3 to 3.5 metres for through lanes on multi-lane roads. The City of Waterloo has shown evidence of a similar transition with lane reductions in recent projects detailed in **Section 5**.

Table 3 provides a succinct summary of findings.

Table 3: Summary of Findings

Topic	Findings
Impact on capacity, speed, and safety	On urban roadways where traffic is frequently interrupted by intersections, narrower lane widths generally encourage slower travel speeds without negatively impacting the safety performance or capacity of a roadway.
Curb lane	The curb lane on a multi-lane roadway may need to be wider than the adjacent through lane to accommodate larger vehicles such as buses and trucks.
Upper lane width limit	Lane widths greater than 3.5 metres do not appear to be appropriate or beneficial for urban environments. Lane widths greater than 4.0 metres can cause excessive speeding and confusion among motorists.
Pedestrian benefits	Narrower lanes support pedestrian-oriented roadway design, by reducing motor vehicle travel speeds, reducing crossing distances, and enabling shorter signal cycles which reduce pedestrian delay at intersections.
Inclusion of gutter	The gutter is typically excluded from the curb lane width measurement, except in the City of Toronto, which measures lane width to the face of curb.
Rural vs. urban context	On roadways with high speeds and low interruptions to traffic flow, such as rural highways and freeways, both safety and capacity increase with wider lanes. In urban and suburban environments, where speeds are typically 70 km/h or less and flow is frequently interrupted, narrower lane widths have no negative impact on capacity or safety performance. Higher speed arterial roads typically warrant wider lanes.
Transition to context-sensitive design	The desired function, context, and design speed of the roadway should be considered when determining lane width. Both the TAC GDGCR and *AASHTO Green Book* have shifted to providing context-sensitive guidance on lane width selection, and provide a range of values and considerations when selecting width rather than prescribing values based on a limited number of variables. The MTO has chosen to retain a prescriptive design approach.
General guidance	Although guidance suggests that lane widths should generally be selected based on the context of the roadway, the following range can be considered for selection: **Arterial urban roadways:** a lane width of 3.3 to 3.5 metres is appropriate for curb lanes where bus and/or truck traffic is expected, while a width of 3.0 to 3.3 metres is appropriate for inside/through lanes. **Two-lane collector roadways:** a lane width of 3.0 to 3.3 metres is appropriate.

6.2 Recommendations

Based on the findings in this memo, the lane widths used in City of Waterloo standard cross-sections are too wide. The consensus of latest best practice is that wide lane widths encourage speeding, result in worsened safety for pedestrian and cyclists, and require longer pedestrian crossing distances at intersections. Wider than necessary lanes may also lead to higher spending on road construction and maintenance for the City of Waterloo, especially as efforts to include more travel modes become more prominent. As such, to be consistent with best practices and comparable cities, the City of Waterloo may consider narrowing lane width requirements and reducing roadway cross-sections.

As has been demonstrated by the review of comparable cities and emerging design guidance, decision-making regarding lane widths can be context-sensitive. It is possible to create a set of tools to narrow lanes and consider trade-offs between speed, capacity, safety, and the intended use of a roadway. However, certain technical guidance is consistent among the review, such as that excessively wide lanes in urban and suburban contexts is likely to result in higher speeds and reduced safety.

In consideration of the review and current best practices, three recommendations for narrowing lane widths and reducing roadway cross-sections are detailed below.

Removal of Centre Median

Centre medians may serve to manage access to the roadway, separate traffic flow, provide traffic calming through vertical elevation, and create landscaping opportunities. The City of Waterloo also utilizes centre medians to provide separated mid-block crossings, where pedestrians have reduced exposure to the roadway and only mind traffic from one direction when crossing. However, in some contexts, it may be beneficial to remove the centre median, particularly where they consume valuable right-of-way and increase overall pedestrian crossing distances.

The City of Ottawa's updated arterial cross-sections remove the centre median in exchange for more space at the boulevard. In this approach, they have reduced pedestrian crossing distances and accommodated wider sidewalks, cycle tracks, multi-use trails, landscaping, and ample buffer from the roadway which is also used for snow storage. In the scenario where a centre median is not provided, standalone pedestrian refuge islands can provide mid-block crossing opportunities without requiring a constant wide roadway, with a narrowed roadway providing several benefits. The City of Waterloo may consider providing an alternative cross-section that allows for the removal of the standard centre median where the context is appropriate with regards to land use, traffic, and other variables. This allows for the provision of additional boulevard space for active transportation facilities and landscaping, while also reducing crossing distances for pedestrians at intersections.

An associated document within the TMP is the Road Crossing and Intersection Enhancements for Active Transportation Memo, which provides additional investigation into crossing treatments and enhancements.

Avoid Lanes wider than 3.5 Metres

Lanes wider than 3.5 metres should not be used in any urban applications, as they promote faster speeds and consume an unnecessary amount of right-of-way. For existing roadway cross-sections, consider visual narrowing of lanes through striping. For lanes adjacent to a curb, consider adding a longitudinal white stripe at a distance of 0.3 metres from the curb (or at the edge of the gutter), to encourage vehicles to operate in a tighter space. When a wide vehicle lane is adjacent to a bicycle lane, narrow the vehicle lane and use the excess width for a painted buffer space between the two.

Narrow Curb Lane in Conjunction with Buffered Bicycle Lane

Where streets have separated bicycle lanes at the curbs, the buffer zone may be used as justification for narrower lanes because they provide shy distance for larger vehicles operating adjacent to them. Narrow curb lanes with a buffer are a recommended approach as the configuration promotes slower vehicle travel speeds and more horizontal separation between vehicles and cyclists in comparison to a wide curb lane and a conventional bike lane. The buffer space may be painted, or may include physical separation measures such as bollards or planters.

The illustration in **Figure 4** demonstrates that providing a 3.0-metre vehicle lane adjacent to a buffered or separated bicycle lane provides sufficient space for operation of a large vehicle, while promoting maximum horizontal separation between vehicles and cyclists. Ultimately, narrower outside vehicle lanes combined with a buffered bicycle lane can achieve passing distance without compromising lane performance.

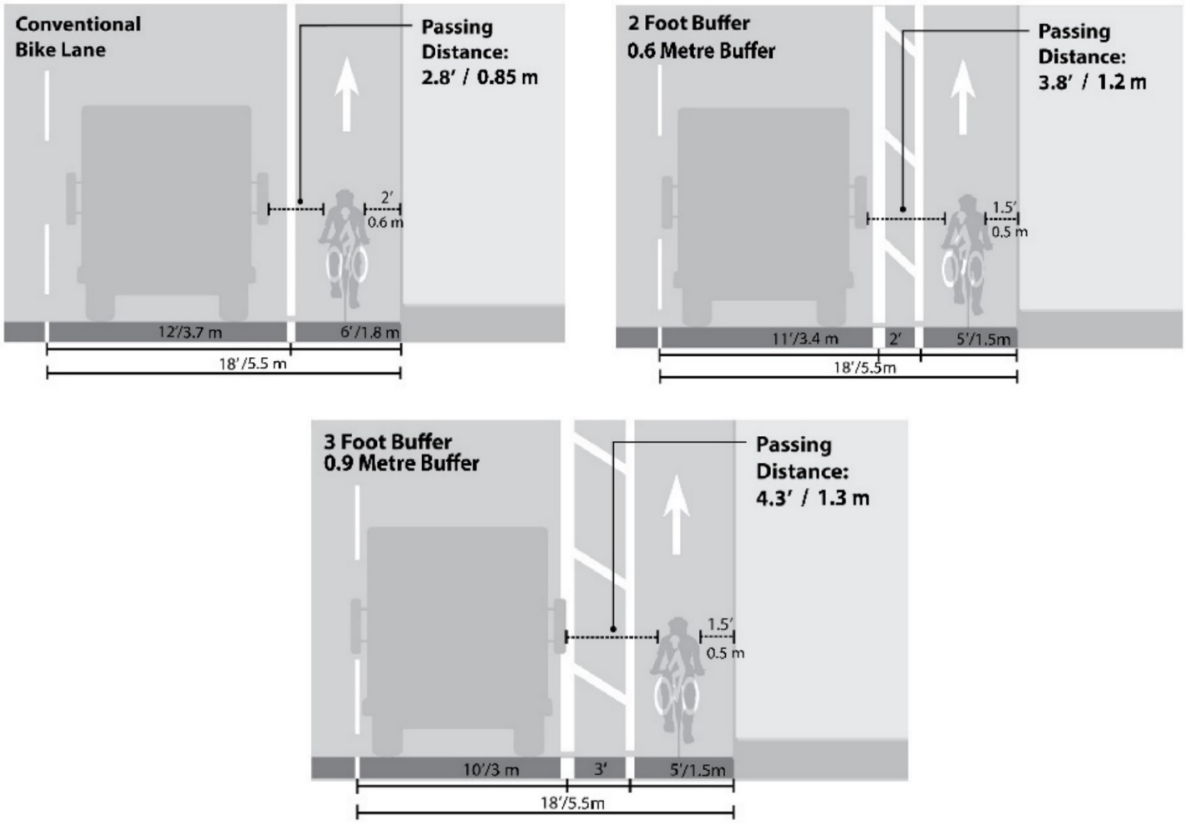
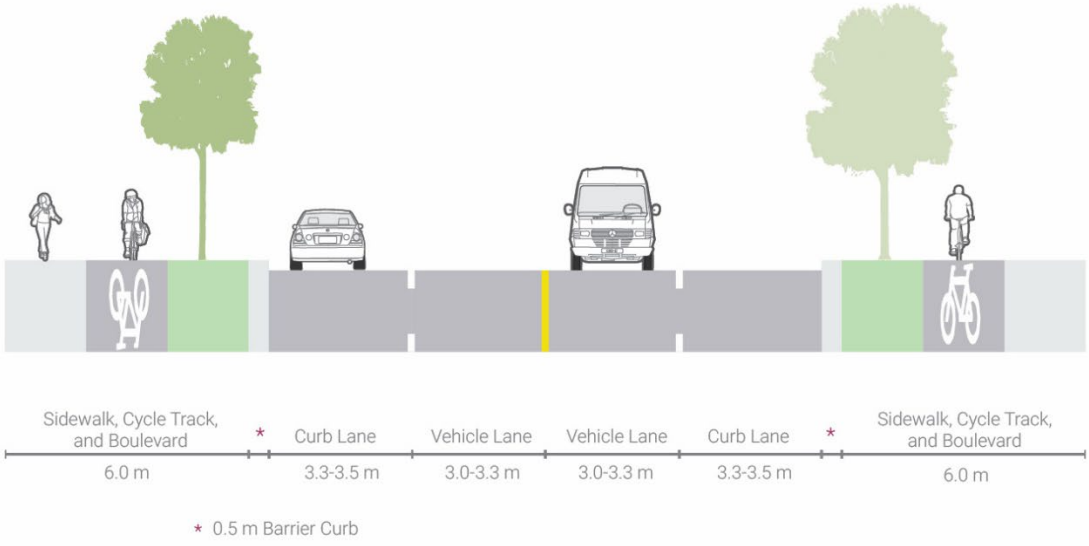


Figure 4 – Narrow Curb Lanes with Buffered Bike Lanes (Source: Alta Planning + Design)

6.3 Sample Revised Cross-sections

Based on the findings of this memo, conceptual cross-sections have been produced for the City of Waterloo for arterial, major collector, and minor collector roadways. The following cross-sections are for discussion purposes only and intend to provide a framework for conversations regarding how to effectively use available space in the right-of-way.

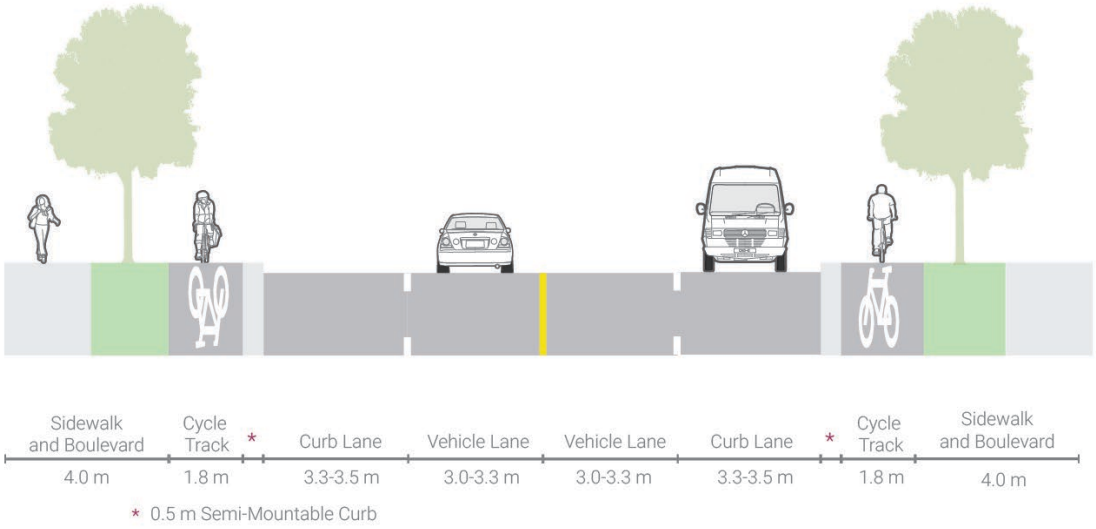
Arterial Cross-section



Cross-section above includes:

- 6.0 metre boulevard including sidewalk, cycle track, and treed boulevard adjacent to curb
- 0.5 metre barrier curb
- 3.3-3.5 metre curb lane
- 3.0-3.3 metre inside lane
- No centre median

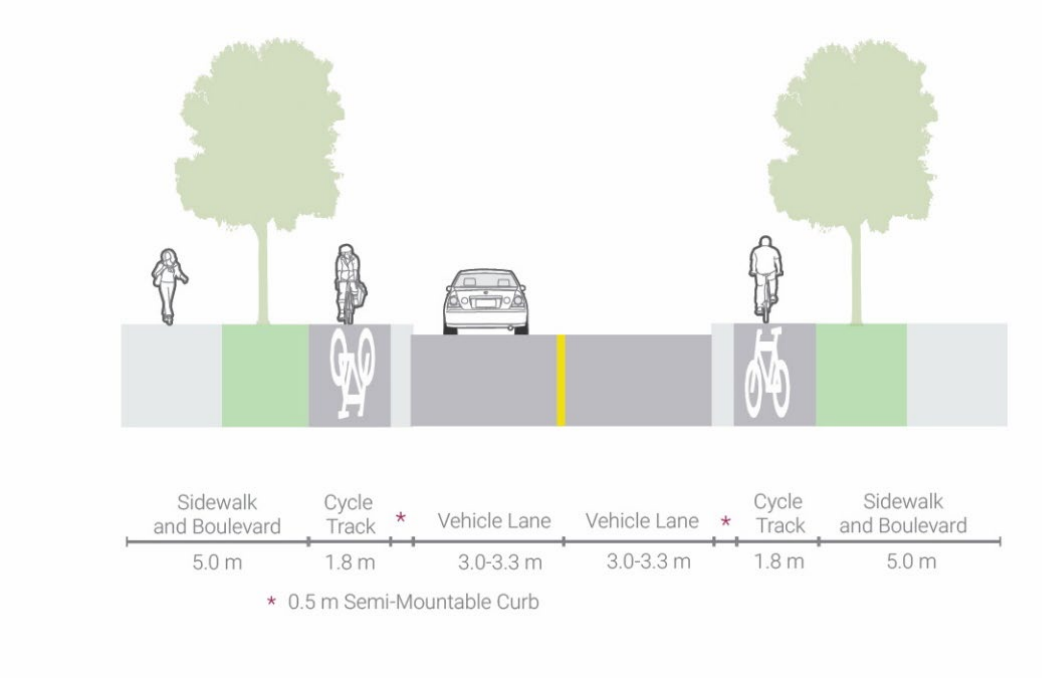
Major Collector Cross-section



Cross-section above includes:

- 4.0 metre boulevard including sidewalk and treed boulevard
- 1.8 metre cycle track
- 0.5 metre semi-mountable curb
- 3.3-3.5 metre curb lane
- 3.0-3.3 metre inside lane
- No centre median

Minor Collector Cross-section



Cross-section above includes:

- 5.0 metre boulevard including sidewalk and treed boulevard
- 1.8 metre cycle track
- 0.5 metre semi-mountable curb
- 3.0-3.3 metre lane
- No centre median

6.4 Impacts to Capital, Maintenance, and Operating Practices

The TMP explores how the City of Waterloo should plan, design, and operate its network to be fiscally sustainable. This is in line with broader policy, where the PPS and Region of Waterloo Official Plan encourage optimization and re-use of existing infrastructure. As such, long-term decision-making regarding lane widths should tie into the Long-Term Financial Plan and the Asset Management Plan, a component of which seeks to evaluate operating impacts of capital projects and new assets. The most significant impact of lane width decision-making is in the required width of total right-of-way. Specifically, the *AASHTO Green Book* details how historical guidance on lane widths has resulted in larger than necessary cross-sections and higher infrastructure and maintenance spending[15]. Narrow lane widths can reduce this historically wide cross-section for capital projects, often resulting in reduced capital, maintenance, and operating costs.

The shift to prioritizing multi-mobility and safety through Complete Streets and Vision Zero has increased the complexity of roadway design, specifically for lane configuration. With cross-sections changing to accommodate cyclists, pedestrians, and transit, the benefits of narrow lane widths can be realized on new and existing roadways in the reduced required width of total right-of-way. Keeping historically wide lane widths may require road widening to accommodate all users, resulting in high capital costs to build and higher operating costs for drainage and maintenance. A transition to narrow lane widths can provide opportunities to re-allocate roadway space to achieve the same goals while reducing capital costs, and maintaining relatively similar maintenance requirements. In some cases, narrow lane widths may allow for the narrowing of roadways or provide space for traffic calming interventions. Additional information on planning-level costs for active transportation facilities is included in the Implementation Costs for Planning Cycling Projects memo of this TMP. The memo further compares projects which require road widening versus those that maintain the existing width of the roadway.

A transition to narrow lane widths often results in re-allocation of roadways space. With no changes in cross-section widths, maintenance and operating costs should remain similar. However, if the result of re-allocation of space is the addition of a variety of new infrastructure and increased complexity due to multi-modal corridors, narrow lane widths can lead to elevated operating or maintenance costs. Increased complexity, such as separated urban bikeways, can require changes in practices for operations such as winter maintenance. A list of typical maintenance considerations that may be impacted by lane width changes to accommodate new facilities has been included below to assist with understanding and evaluating impacts on individual corridors. For more information on winter maintenance as it relates to active transportation facilities, refer to the Winter Maintenance for Active Transportation memo of the TMP.

- Inspections
- Pavement sweeting and blowing
- Snow plowing and ice removal
- Litter removal
- Crack sealing and repair
- Pavement marking replacement
- Roadway resurfacing and reconstruction
- Culvert and drainage grate inspection
- Major damage response
- Pothole repair

6.5 Benefits Statement

On urban roadways, narrower vehicle travel lanes have the ability to manage or reduce speed and shorten crossing distances for pedestrians while providing space for additional elements in the right-of-way such as cycling facilities, on-street parking, transit stops, landscaping, or turning lanes, without negative impacts to safety or capacity.

[1] Transportation Research Board, *Design Factors That Affect Driver Speed on Suburban Streets,* Fitzpatrick, K., Carlson, P., Brewer, M., Wooldridge, M. Transportation Research Record Report No. 1751, (2001).
[2] Ibid.
[3] Organization for Economic Co-operation and Development, *Behavioral Adaptations to Changes in the Road Transport System*, Road Transport Research, Scientific Expert Group. Paris: 1990.
[4] U.S. Department of Transportation Federal Highway Administration, *Self-Enforcing Roadways: A Guidance Report,* Donnell, E., Kersavage, K., Tierney, L.F. Report No. FHWA-HRT-17-098, Washington, DC: 2018.
[5] Hussain, Q., Feng, H., Grzebieta, R., Brijs, T., Olivier, J., "The relationship between impact speed and the probability of pedestrian fatality during a vehicle-pedestrian crash: A systematic review and meta analysis," *Accident Analysis & Prevention*, 129, (2019): pp. 241-249.
[6] National Association of City Transportation Officials, *Designing for All Ages & Abilities: Contextual Guidance for High-Comfort Bicycle Facilities,* (2017).
[7] Transportation Association of Canada, *Geometric Design Guide for Canadian Roads,* (2017).
[8] National Association of City Transportation Officials, *Urban Street Design Guide,* (2013).
[9] Transportation Research Board of the National Academies, *Relationship of Lane Width to Safety on Urban and Suburban Arterials*, Potts, I., Harwood, D. and Richard, K.R. Transportation Research Report No. 2023, Washington, DC: 2007.
[10] Ogden, K.W. "Safer Roads: A Guide to Road Safety Engineering," Castle Hill, Australia: Avery Technical, (1995).
[11] Transportation Research Board. *HCM 2010: highway capacity manual*. Washington, D.C.: Transportation Research Board, (2010).
[12] Transportation Association of Canada. *Geometric Design Guide for Canadian Roads*. (2017).
[13] City of Ottawa. *Building better and smarter suburbs: strategic directions and action plan.* (2015). Retrieved from https://documents.ottawa.ca/sites/default/files/documents/BBSS_final_en.pdf
[14] Ibid.
[15] American Association of State Highway and Transportation Officials (AASHTO). *A Policy on Geometric Design of Highways and Streets.* (2018).

11 VISION ZERO

Technical Memorandum

Date: August 13, 2020

To: Christopher Hodgson, City of Waterloo

From: Gene Chartier, Paradigm Transportation Solutions Limited

c.c.: Kate Whitfield, Alta Planning + Design
Susan Hall, Lura Consulting

Re: **Vision Zero**

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1 Introduction

The *City of Waterloo 2019-2022 Strategic Plan* approved by City Council on June 24, 2019 establishes "safe, sustainable transportation" as a strategic pillar (or area of focus) for the municipality. "Safe, sustainable transportation exists when all users and all modes of transportation are able to share roadways and trail systems safely; when traffic speeds respect the safety of the community; when policy and planning supports the development and maintenance of sustainable infrastructure; and when more residents are able to rely on sustainable modes of transportation such as public transit or active transportation to get where they need to go".[1]

The Strategic Plan sets out two objectives related to the goal of "improving all modes of transportation to make Waterloo more mobile, accessible and connected", being:[2]

- Adopt Vision Zero practices and tactics to enable safe travel by all modes of transportation.
- To facilitate a modal shift, enable increased use of active transportation and public transit.

Other investigations completed for the **City of Waterloo Transportation Master Plan (TMP) Update** have examined opportunities and proposed strategies to increase the use of active transportation and public transit. This memorandum explores the topic of Vision Zero, providing the foundation for the road safety policies and initiatives being recommended by the TMP Update (i.e., 40 km/h speed limits on certain City streets, addressing identified collision locations). Vision Zero also relates to the Complete Streets and active transportation directions of the plan.

The memorandum is organized as follows:

- Chapter 2 explains Vision Zero and highlights best practices relevant to the City of Waterloo;
- Chapter 3 documents existing City road safety policies, guidelines, and practices and how they relate to Vision Zero;
- Chapter 4 summarizes Vision Zero initiatives underway in other Ontario municipalities;

- Chapter 5 outlines the recommended approach for moving forward with Vision Zero in Waterloo;
- Chapter 6 identifies potential impacts on capital, operating, and maintenance practices resulting from implementation of Vision Zero principles;
- Chapter 7 provides a benefits statement; and
- Chapter 8 lists the documents referenced in preparing the memorandum.

2 Background

2.1 What is Vision Zero?

Vision Zero is a strategy to eliminate traffic fatalities and severe injuries, while increasing safe, healthy, equitable mobility for all. Originating in Sweden in the late 1990's, Vision Zero is based on the philosophy that:

- No loss of life is acceptable;
- Traffic fatalities and serious injuries are preventable;
- People make mistakes so the road system and related policies should be designed to ensure those inevitable lapses do not result in severe injuries or fatalities; and
- Humans are physically vulnerable when involved in motor vehicle collisions.[3]

Vision Zero starts with the ethical belief that everyone has the right to move safely in their communities. The concept deviates from the traditional view of road safety in two primary ways (see right):

Source: Vision Zero Network https://visionzeronetwork.org/about/what-is-vision-zero/

- System designers and policymakers share responsibility for ensuring safe travel with road users and are expected to improve the roadway environment, policies (such as speed management), and other related systems to lessen the severity of collisions; and
- Addressing this complex problem requires a multidisciplinary, collaborative approach, bringing together diverse stakeholders such as traffic planners and engineers, enforcement personnel, policymakers, and public health professionals.

While not a new concept, Vision Zero requires a shift in how communities approach decisions, actions, and attitudes around safe mobility. The philosophy focuses on the policies and street designs with the greatest impact on safety. Different implementation approaches exist including:

- The **Safe Systems Approach**, which aims to create a road system that makes allowances for errors and minimizes their consequences, particularly the risk of death or serious injury, by targeting four elements:

- Safe Speeds – Driving at an appropriate speed reduces the likelihood of a collision, diminishes injury severity if a crash does occur, and provides a safety buffer by giving motorists sufficient time to stop in an emergency;
- Safe Roads – Roads can function to help manage speeds, reduce complexity, allow for human error, provide positive guidance to drivers, and reduce crash forces on people;
- Safe Vehicles – Emerging technologies such as inflatable seat belts, centre air bags, crash avoidance systems, forward-collision warning, traffic sign recognition, adaptive headlights, lane-departure systems, intelligent speed assistance, fatigue-monitoring, and pedestrian detection can improve safety; and
- Safe Drivers – Educating drivers and enforcing the rules of the road can help reduce driver error, a contributing factor in many collisions.

- The **"Es" of Traffic Safety**, which commonly provide the framework for Vision Zero planning in Canada. The most often used Es are "Engineering", "Enforcement", "Evaluation", "Education" and "Engagement". Sometimes additional "Es", such as "Equity", or different variations, like "Encouragement" rather than "Engagement", may be cited depending on the plan and purpose.
- A **Complete Streets Framework**, which emphasizes the design of streets for all ages, abilities, and modes of travel, including walking, cycling, transit, and others, consistent with objectives contained in the TMP.
- The **Public Health Approach**, which is preventative in nature and involves understanding the underlying determinants of health problems and developing effective strategies in response.

Communities making a Vision Zero commitment believe the status quo is unacceptable and systemic changes are needed to achieve meaningful progress in road safety. Committing to the vision requires:

- Building and sustaining leadership, collaboration, and accountability among a diverse group of stakeholders;
- Collecting, analyzing, and using data to understand trends and potential disproportionate impacts of traffic fatalities on certain populations;
- Prioritizing equity (all potential stakeholders) and community engagement in devising strategies and developing action plans; and
- Setting a timeline to achieve zero traffic deaths and serious injuries, which brings urgency and accountability and ensures transparency on progress and challenges.[4]

Typical focus areas for Vision Zero initiatives include:

- Positioning road safety as a top priority in policymaking;
- Improving road infrastructure for all road users;
- Enhancing the safety of vulnerable road users;
- Increasing enforcement of laws to manage safe speeds and reduce impaired and distracted driving;
- Strictly regulating and testing vehicles;
- Leveraging innovative technology (red light cameras, automated speed enforcement); and
- Continuing leadership, collaboration, and accountability among all stakeholders.[5]

Key activities to ensure Vision Zero becomes a reality include:

- Road infrastructure changes;
- Enhanced regulation and enforcement;
- Advocacy for policy change; and
- Raising public awareness and commitment to road safety. [6]

Making a Vision Zero commitment requires time, effort, collaboration, and patience to achieve meaningful results, but is valued in communities that have moved in this direction.

2.2 Best Practices

2.2.1 Parachute Vision Zero

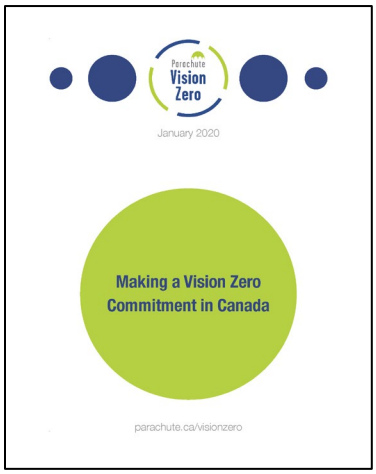
Parachute, founded in 2012 through the amalgamation of four charities in the injury prevention field, has become Canada's leader in injury prevention. The organization educates and advocate for preventing serious injury in homes, in sports and recreation, and on roads.[7]

Parachute has taken a lead nationally to co-ordinate and share Vision Zero best practices with municipalities and communities seeking to improve road safety. The organization works to:

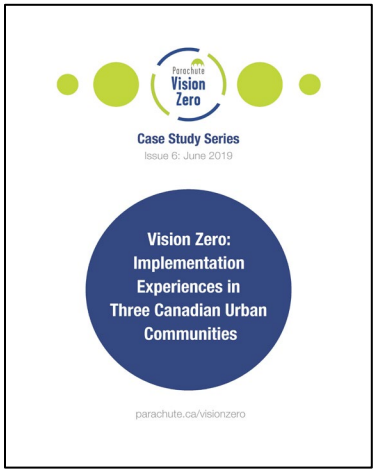
- Create and disseminate evidence-based Vision Zero resources and best practices in road safety;
- Support urban and rural jurisdictions in their understanding and adoption of Vision Zero;
- Connect key road safety stakeholders to increase the overall awareness and effectiveness of the Vision Zero approach; and
- Support data-driven approaches to road safety.

The following summarizes two of the many Vision Zero publications produced by Parachute Vision Zero that are applicable to the TMP Update:

- *Making a Vision Zero Commitment in Canada*[8] (2020) provides guidance on the implementation of Vision Zero in Canada. The report briefly summarizes the roots of the movement and the status of Vision Zero across Canada, including a high-level review of road safety frameworks in place nationally. By using an injury-prevention approach based in public health theory, the paper provides information not only on Vision Zero-specific implementation but also addresses the contextual factors that impact these efforts, such as community readiness. Tools created by Parachute and others supplement the report, providing useful resources for stakeholders at all stages of their Vision Zero commitment.



- *Vision Zero: Implementation Experiences in Three Canadian Urban Communities*[9] (2019) describes the experiences, challenges, and solutions of three communities in Canada in adopting Vision Zero: Surrey, Durham Region and Kingston. For each community, the report explains the rationale for developing a Vision Zero plan, lists the specific actions carried out, and presents an interview with a local representative on implementation. Lessons learned from their experience include:
    - Obtain data from a reliable source as evidence;
    - Research is key to supporting decisions;
    - Establish respectful and productive working relationships with police services, council, and other community stakeholders;
    - Prioritize vulnerable road users over vehicle movements during road design, especially at intersections; and
    - Recognize results will not be immediate.

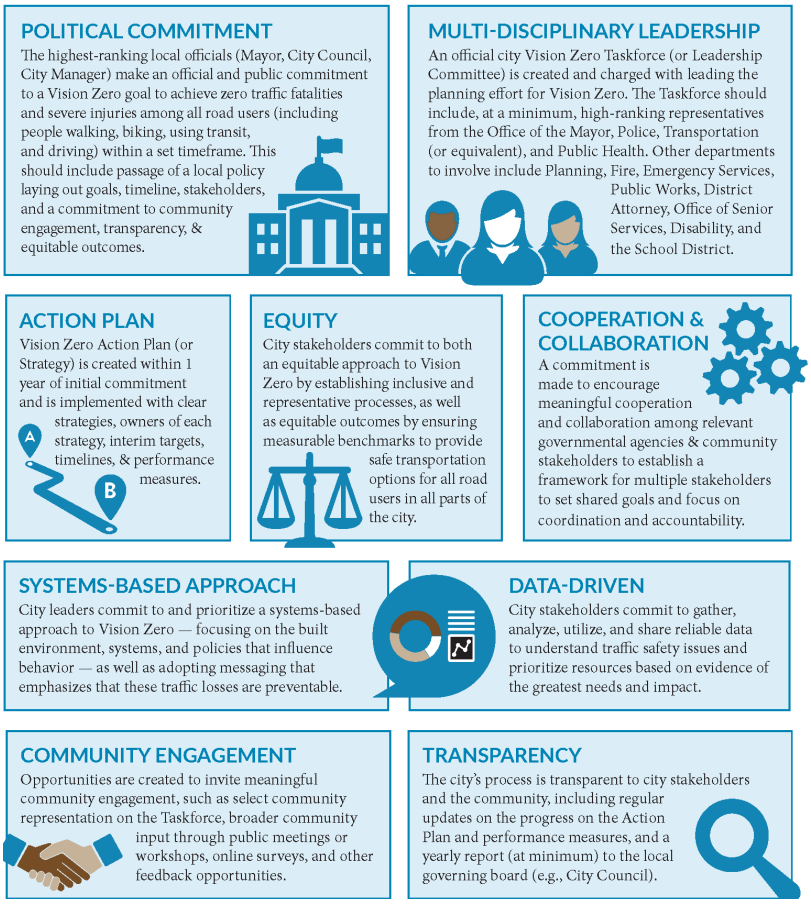


2.2.2 Vision Zero Network

The Vision Zero Network[10] is a collaborative campaign based in the United States. Like Parachute Vision Zero, the Network offers a broad range of resources to help communities implement Vision Zero plans including a list of nine components proven to be an effective high-level framework for municipalities considering a vision commitment (see right). While not the only factors to consider, they are critical aspects to ensuring a strong and lasting commitment to Vision Zero.

The Vision Zero Network recognizes municipalities taking demonstrable and significant actions to ensure safe mobility for all. To be recognized as a Vision Zero community:

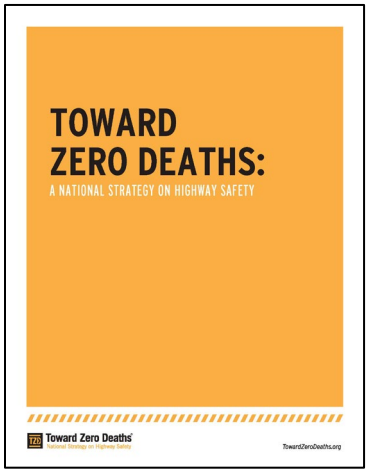
- The municipality must set a clear goal of eliminating traffic deaths and serious injuries among all road users within an explicit timeframe (i.e. 10 years);



Source: Vision Zero Network
https://visionzeronetwork.org/wp-content/uploads/2018/05/VZN-9-Components.pdf

- The Mayor (or top elected official) must publicly commit to becoming a Vision Zero community within the set timeframe and direct appropriate municipal staff to prioritize the work;
- The municipality must have a data-driven, equitable Vision Zero Action Plan or Strategy in place, or the Mayor and key departments must commit to adopting one in a specified time frame, including community input;
- Key departments, including transportation, public health, Mayor's office, and law enforcement, must be actively engaged as leaders and partners in the process of developing the Vision Zero Plan, implementing the strategy, and evaluating and sharing progress; and
- A Vision Zero Task Force (including the agencies listed above, as well as community stakeholders and others) must meet regularly to lead and evaluate efforts.

2.2.3 Toward Zero Deaths: A National Strategy on Highway Safety (2014)



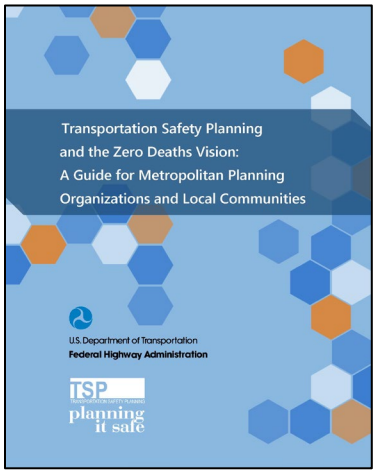
The Toward Zero Deaths (TZD) *National Strategy on Highway Safety* (the National Strategy)[11] is a long-term strategy to bring together the various stakeholders nationwide in the United States with a role in highway safety. The National Strategy defines the common vision to guide the individual and collaborative efforts of safety stakeholders as "a highway system free of fatalities through a sustained and even accelerated decline in transportation-related deaths and injuries."

The National Strategy identifies key safety focus areas to ensure the greatest progress and unite all efforts of a wide array of stakeholders nationwide. These focus areas include:

- Safer drivers and passengers;
- Safer vulnerable users;
- Safer vehicles;
- Safer infrastructure;
- Enhanced emergency medical services; and
- Improved safety management and data processes.

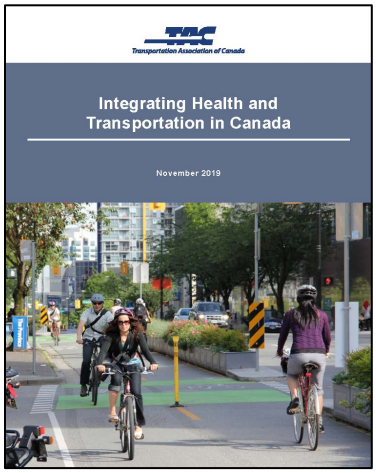
The National Strategy builds on existing stakeholder efforts and encourages continued use of proven programs and countermeasures in a proactive, multidisciplinary manner. Additionally, the document provides a discussion on encouraging a transportation safety culture and highlights the key initiatives to prioritize long-term to achieve the vision.

2.2.4 Transportation Safety Planning and the Zero Deaths Vision: A Guide for Metropolitan Planning Organizations and Local Communities (2018)



The US Federal Highway Administration (FHWA) publication *Transportation Safety Planning and the Zero Deaths Vision: A Guide for Metropolitan Planning Organizations and Local Communities*[12] assists agencies and stakeholders in using the safety planning process to work toward the zero deaths vision. The guide supports developing, implementing, and evaluating performance-based strategic safety plans. It shows how practitioners can engage in safety planning efforts and sets out a process for addressing safety in a proactive manner based on the following process: analyze data; set goals and targets to facilitate a performance-based planning approach; identify strategies to address safety challenges; prepare the plan document; and evaluate the effectiveness of the plan.

2.2.5 Integrating Health and Transportation in Canada (2019)



The Transportation Association of Canada (TAC) publication *Integrating Health and Transportation in Canada*[13] is a resource to further enhance the integration of transportation, land use and health-related initiatives in Canada. Awareness continues to grow of the opportunity and need to use transportation and land use activities to achieve public health goals such as injury prevention, increased physical activity, reduced chronic diseases, and reduced exposure to air and noise pollution. Good health can be facilitated or negatively impacted by transportation policies, plans, analyses, funding levels, and infrastructure design decisions – all of which impact the relative safety, efficiency, costs, and overall desirability and relative utility across modes of travel. Transportation and land use actions shape each other, as well as activity patterns and health outcomes, and their associated costs.

The report provides 11 recommendations to better integrate transportation, land use, and health spanning the categories of:

- Education and professional development;
- Policy and practice; and
- Expanding and evidence.

2.2.6 Defending Vision Zero (2017)

As the number of cities enacting versions of Vision Zero in their communities increases, there is growing concern that the foundation of the policy is shifting and being diluted. In "Defending Vision Zero"[14], author Claes Tingvall, the former Director of Traffic Safety for the Swedish Transport Administration when the policy was enacted, argues that communities must maintain and defend the integrity of Vision Zero as the philosophy spreads across the globe. In the article, Tingvall writes:

Vision Zero must be a policy based on ethics, shared responsibility and must use only scientific methods to eliminate death and serious injury. In its inception, this was based in three ideas:

First, Vision Zero states that the traditional trade-off between mobility and safety is banned. Mobility is a function of safety, which means that safety comes first in the design and functionality of any transportation system. An investment in safety is therefore an investment in functionality, accessibility or mobility, and in reality there is no conflict.

Second, the responsibility for safety is divided between the providers of the transportation system and the users. The user is expected to follow the basic rules of the transportation system, like staying sober, obeying speed limits and wearing a seat belt. Everything else falls on the providers, and the providers are a broad group of people: policymakers, elected officials, trucking companies, city planners and traffic engineers are all included. If the road user fails to follow the basic rules, the responsibility falls back on the providers to come up with new solutions.

Third, all decision-making around Vision Zero should be based on science and documented experience. Providers must be evidence-based in their decisions, because they are responsible for the life and health of users. There is no room for experimenting with methods that have proven ineffective. Like doctors, providers' only prescriptions for roads should be those which have been proven to be effective and safe. Since more than 90% of all crashes can be attributed to human error, the transportation system must be robust and tolerate human errors.

From these three cornerstones, we can fairly well distinguish between what is Vision Zero and what it is not. Our most important work, as Vision Zero spreads around the world, is drawing this line in the sand.

3 Existing Practice in the City of Waterloo

The City of Waterloo has a long history of implementing road safety initiatives consistent with the principles of Vision Zero. The municipality is already engaged in numerous efforts to improve road safety in Waterloo through its participation on various committees and implementation of different safety-oriented policies and programs. Past, ongoing, and impending activities include:

Committees

City representatives participate on several committees and organizations focused, in large part, on road safety, including:

- School Transportation Services of Waterloo Region (STSWR) – Schools, school boards, parents, and municipal staff work collaboratively to encourage greater use of active transportation for school travel;
- Regional Transportation Coordinating Committee (RTCC) – Regional and area municipal staff and police services meet to share best practices and coordinate road safety initiatives;
- Waterloo Advisory Committee on Active Transportation (WACAT) – The Committee advocates for and advises Council on active transportation;

- Regional Roundabout Coordination Committee – Regional, area municipal and Grand River Transit staff meet to assess and consider potential roundabout locations; and
- Selective Traffic Enforcement Program (STEP) – The City works actively with Waterloo Regional Police Services to target high speed and collision enforcement.

Policies and Programs

The City has a range of existing policies and programs influencing or related to road safety including:

- Traffic Calming Policy (including traffic calming studies and implementation)
- LED Conversion (enhances pedestrian and vehicle vision at night)
- 40 km/h Speed Limits within School Areas
- Annual Collision Report
- Review and Design of Capital Road Reconstruction Projects (to incorporate road safety aspects)
- Review and Design of Site Plan Developments
- Radar Speed Boards
- Flexible Median Signs (aka knock-down signs)
- Sidewalk Policy
- Sidewalk Prioritization (for implementing new infill sidewalks)
- Pedestrian Refuge Island Installations
- School Crossing Guards
- Complete Streets Policy
- Annual Data Collection:
  - Automated Traffic Recording (ATR) (for average daily traffic on road segments)
  - 8-hour Turning Movement Counts (TMC) (for calculating traffic control warrants at intersections and includes pedestrians and cyclists counts)
  - Priority Trail Network Counting Program (Eco-counters)
- Regional Red Light Cameras
- Coordinated Education Campaigns (with Waterloo Regional Police Services)
- Cycling Education and Outreach Programs (including CANBike training, elementary schools, cycling education videos on website, helmet distribution program)
- Bi-annual Cycling Report and Annual Sidewalk Report

The City is also pursuing the following initiatives:

- Pedestrian Crossover (PXO) Implementation and intersection/road crossing enhancements
- Enhanced Radar Board and Flexible Median Signs
- Network Screening and Collision Countermeasure Program
- Automated Speed Enforcement
- Trail lighting program
- A focus on separated cycling and a new `Primary Cycling Network'
- Establishing a winter maintained active transportation network
- Pilot 40km/h in community neighbourhoods
- Emerging technologies in autonomous vehicles and systems

4 Review of Comparable Cities

Beyond Sweden, cities throughout the United States, New Zealand, Australia, the United Kingdom, Japan, India, Germany, the Netherlands, Poland, and Norway have made Vision Zero commitments. Cities across Canada have also acted against preventable traffic-related tragedies and serious injuries. Efforts began in Edmonton in 2015 and have continued to spread across the country, from the municipal and provincial/ territorial levels to a national Vision Zero road safety strategy. At present, about 20 Canadian jurisdictions have committed to Vision Zero. In certain cases, these plans, strategies, and approaches take on different names, depending on the level of commitment and goals of the community. Some use terms like “Towards Zero” and “Road to Zero” to communicate their goal of zero fatalities and serious injuries while not specifically branding the initiative as Vision Zero.

In Ontario, the single and upper-tier jurisdictions listed below have implemented Vision Zero (or similar) initiatives (year of the last plan update noted in parentheses). No lower-tier municipalities in the province have committed to Vision Zero:

- City of Brantford (2018)
- City of Hamilton (2019)
- City of Kingston (2019)
- City of London (2017)
- City of Ottawa (2020)
- City of Toronto (2019)
- Region of Peel (2017)
- Region of Durham (2019)

The Cities of North Bay and Windsor are also considering initiatives.

The Vision Zero plans for these municipalities typically include:

- A summary of existing safety programs, policies, and strategies;
- A road safety vision, mission, and goals for the municipality to be achieved through the plan;
- A focus on the Safe Systems Approach and the “E’s” of safety (enforcement, education, engagement, engineering, evaluation, empathy) in structuring programs;
- A list of target/emphasis areas for safety improvement (between 5 and 10) based on collision history and/or public input (e.g., intersections, distracted/aggressive/impaired driving, young drivers, pedestrians, cyclists, red light running, etc.);
- A series of actions or countermeasures to address each emphasis area; and
- A high-level action plan identifying the specific road safety measures to be implemented by year with a cost estimate. Common components include data collection, evaluation and monitoring, and prioritization.

Some municipalities have also identified a goal of reducing fatal and injury collisions by 10% within five years.

Examples of safety initiatives implemented through these Vision Zero (and other road safety) plans include:

- Speed Limit Reviews
- Active and Sustainable School Transportation
- Red Light Camera Program
- Network Screening Program
- Collision Counter Measure Program (CCM)
- Ladder Crosswalk Program
- Pedestrian Mobility Plan
- Helmet Initiatives
- Complete, Livable, Better Streets
- School Zone Safety Program
- Traffic Calming Program
- Distracted Driving Campaign
- Slow Down, Safety Zone Lawn Sign Program
- Pedestrian Crossover Program
- Vision Zero Awareness Programs

5 Recommended Actions

5.1 Considerations in Committing to Vision Zero

The City's existing road safety actions include many of the initiatives cited in the Vision Zero plans reviewed. Like the communities with these plans, the City is taking a multi-disciplinary approach to road safety, in part through its participation on different committees, and has a range of policies and programs aimed at improving safety. But unlike these municipalities, Waterloo does not have a comprehensive, structured program with stated objectives, expected outcomes, and committed funding.

Fortunately, the City experiences very few traffic-related fatalities and serious injuries on roads under its jurisdiction. While the City should always remain vigilant and dedicated to eliminating severe outcomes from motor vehicle collisions, one could question the necessity of committing to Vision Zero at this time given its road safety history. Making this commitment would likely require considerable investment in infrastructure changes and/or electronic enforcement to compel drivers to further reduce vehicle speeds and comply with other traffic rules (e.g., stop sign and red light running). Experience has shown signs and markings alone have limited long term effect. On the other hand, physical measures can adversely impact emergency response (fire, ambulance, and police) and transit service delivery. As well, the design and operation of the road is also only one factor contributing to traffic-related fatalities and serious injuries. Driver behaviour and the vehicle, factors largely outside the City's control, also play a critical role.

The City would also need to consider the public expectations of committing to Vision Zero. Making the commitment would likely change community perception on how the City prioritizes road-related initiatives and level of expenditure. It is also conceivable some will view any motor vehicle collision with

a severe outcome to be a failure of the program and insist on a City response notwithstanding the cause of the event or effectiveness of the potential countermeasure.

Current City traffic safety programs are based on the same philosophy as Vision Zero and offer the same breadth of perspective, in that the City incorporates education, enforcement, engineering, evaluation, and engagement in its initiatives. From a safety perspective, the City's road network appears to be performing better than others in Canada and even in Sweden based on research completed by the Region of Waterloo. But the City is always striving for improvement, particularly as there is a renewed emphasis on increasing mobility by active transportation and transit.

5.2 Moving Forward

One cannot argue against Vision Zero on an ethical basis. Fatalities and serious injuries are unacceptable outcomes of motor vehicle collisions. But formally committing to Vision Zero presents several important factors and potential consequences for the City to consider as noted above.

City Council has expressed a strong desire in committing to Vision Zero as evidenced by its stated objectives in the *City of Waterloo 2019-2022 Strategic Plan* and commentary provided throughout the TMP Update process. Consistent with this direction, the City should articulate a formal policy on road safety that pledges to Vision Zero and captures the key tenets of this strategy. This policy could read:

> *As a Vision Zero community, the City of Waterloo, with the support of its partners, aims to eliminate traffic-related fatalities and serious injuries on City roads using a Safe Systems Approach consistent with its Complete Streets Policy.*

Along with adopting this policy, the City should develop a Road Safety Action Plan (RSAP), consolidating its traffic safety-related initiatives into one comprehensive strategy with clear objectives, stated outcomes, and required funding. The RSAP should follow the Safe Systems Approach, implementing evidence-based measures for safe drivers, safe speeds, safe roads, and safe vehicles.

The City should also pursue new methods of identifying locations and trends with potential for safety improvement (consistent with the recommendations of the TMP Update memorandum "Addressing Identified Collision Locations") and implement proven countermeasures. Additionally, the City should consider trial applications of emerging countermeasures on a site-specific basis to evaluate their potential benefit in Waterloo. The availability of new technology, such as automated and connected vehicles, may also have a positive influence on the future of road safety.

6 Impacts on Capital, Maintenance, and Operating Practices

The recommended road safety policy and RSAP will provide the foundation for how the City plans, prioritizes, and implements its safety-related programs. Once completed, the RSAP will set-out the City's safety programming and funding requirements for capital projects. The plan will also influence ongoing maintenance and operations priorities for the City.

The funds allocated to road safety in the City's budget should focus on the actions recommended in the RSAP, with locations and initiatives demonstrating the greatest potential for safety improvement

prioritized for implementation. This document will influence the required financing and how funds are allocated for safety-related capital projects and maintenance and operations practices.

Moving forward, the City should ensure safety-driven improvements are prioritized against mobility and state-of-good repair initiatives. Like other jurisdictions, funding for safety countermeasures is somewhat limited, necessitating the allocation of funds to the highest priority programs. Data-driven, evidenced-based methods of selecting and prioritizing initiatives should be included in the RSAP or developed as an outcome. Opportunities to coordinate safety improvements with other initiatives, like road rehabilitation projects, should also be explored (this is consistent with Waterloo's existing Complete Streets policy).

If Council agrees to this approach to continue current programs and support the upcoming programs, there will be strategic budgetary items required for capital, maintenance, and operations initiatives. Staff will work through the budget process to implement current and future planned programs and initiatives.

7 Benefits Statement

By adopting the road safety policy and developing a Road Safety Action Plan, the City will move towards achieving its goal of safe sustainable transportation – a strategic objective of the City's Strategic Plan. The programs and actions implemented through the RSAP will reduce traffic-related fatalities and serious injuries, helping to enable safe travel by all modes of transportation and facilitate increased use of active transportation and public transit.

8 References

1 City of Waterloo. *City of Waterloo 2019-2022 Strategic Plan Report*. p. 10. July 2019.

2 City of Waterloo. *City of Waterloo 2019-2022 Strategic Plan Report*. p. 10. July 2019.

3 Parachute Vision Zero. *Making a Vision Zero Commitment in Canada*. January 2020.

4 Vision Zero Network. *A Primer on Vision Zero – Advancing Safe Mobility for All.* 2018.

5 Parachute Vision Zero. *Committing to Vision Zero*. 2019.

6 Parachute Vision Zero. *Committing to Vision Zero*. 2019.

7 https://parachute.ca/en/program/vision-zero/ [Accessed 2020-06-24]

8 Parachute Vision Zero. *Making a Vision Zero Commitment in Canada*. January 2020.

9 Parachute Vision Zero. *Issue 6 Vision Zero: Implementation Experiences in Three Canadian Urban Communities*. June 2019.

10 https://visionzeronetwork.org/about/vision-zero-network/ [Accessed 2020-06-09]

11 Toward Zero Deaths. *National Strategy on Highway Safety*. June 2014.

12 Federal Highway Administration. *Transportation Safety Planning and the Zero Deaths Vision: A Guide for Metropolitan Planning Organizations and Local Communities*. Washington, DC. August 2018.

13 Transportation Association of Canada. *Integrating Health and Transportation in Canada*. Ottawa, ON. November 2019.

14 Tingvall, Claes and Maria Krafft. “Defending Vision Zero”. Vision Zero Cities 2017, International Journal of Traffic Safety Innovation. Transportation Alternatives. Volume 2. May 2017.

12 ASSESSMENT OF AREA-WIDE SPEED LIMITS ON CITY STREETS

TRANSPORTATION MASTER PLAN
LOOKING AHEAD

THE CITY OF Waterloo

Technical Memorandum

Date: September 23, 2020

To: Christopher Hodgson, City of Waterloo

From: Gene Chartier, Paradigm Transportation Solutions Limited

c.c.: Kate Whitfield, Alta Planning + Design
Susan Hall, Lura Consulting

Re: **Assessment of Area-Wide Speed Limits on City Streets**

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1 Introduction

As part of the **City of Waterloo Transportation Master Plan (TMP) Update**, the City is assessing the implications of reducing the speed limit on City streets in residential neighbourhoods from the statutory rate of 50 km/h to 40 km/h. This memorandum:

- Reviews the experience of other Canadian municipalities that have adopted or are considering area-wide speed limit reductions, assessing their successes and challenges, before and after data (if available), and community response/reaction to the initiative;
- Identifies potential issues and impacts on capital, operating and maintenance practices for Waterloo as well as legal implications resulting from an area-wide speed limit reduction; and
- Assesses the potential benefits and consequences of area-wide speed limit reductions and highlights important considerations should the City wish to move forward.

In this assessment, the term “area-wide” could mean an entire municipality, a specific community or a defined corridor, block, or section of road, with the primary focus being residential neighbourhoods.

2 Background

2.1 Origin

The Cities of Kitchener and Waterloo have an established history of collaboration and cooperation. In 2006, the cities formed the Kitchener-Waterloo Joint Services Initiatives Committee (JSIC) to identify shared and common services and explore opportunities to streamline their delivery to the benefit of residents in both municipalities.

In 2019, the cities initiated a review of neighbourhood speed limits through the JSIC. This review is evaluating the benefit and feasibility of reducing the uniform speed limit from 50 km/h to 40 km/h to enhance roadway safety. The City of Waterloo's review is being undertaken through the TMP Update, with this memorandum serving as the technical assessment.

City arterial roads and Regional Roads, such as Columbia Street, Weber Street, Westmount Road and Fischer-Hallman Road, are not included in this review. Instead, the review focusses on local and collector residential streets including Eastbridge Boulevard, Westvale Drive, Keats Way, and Northlake Drive.

2.2 Rationale for Lower Speed Limits

Studies show that speeding is a significant contributing factor to severe injury and fatal collisions worldwide. The likelihood of a pedestrian surviving a collision with a motor vehicle is approximately 15% when the vehicle is travelling at 50 km/h but increases to 75% when the vehicle is moving at 40 km/h or less.

Higher speeds not only escalate the risk of severe injury and fatal collisions, but also increase the probability of a crash happening in the first place. Vehicles travelling at higher speeds require a greater distance to stop safely due to reductions in both braking and driver reaction times available to prevent a collision from happening. A stopping distance of approximately 85 metres is required for a vehicle travelling at 60 km/h but only 45 metres at 40 km/h.

As well, communities are placing greater emphasis on multi-modal transportation with sustainable planning and design philosophy changing how urban streets and centers look and function. Streets are now viewed as public places with space being allocated for all modes of transportation and different road users. Planning and design approaches are changing to accommodate this shift in philosophy, which aligns strategically with both Complete Streets and Vision Zero principles.

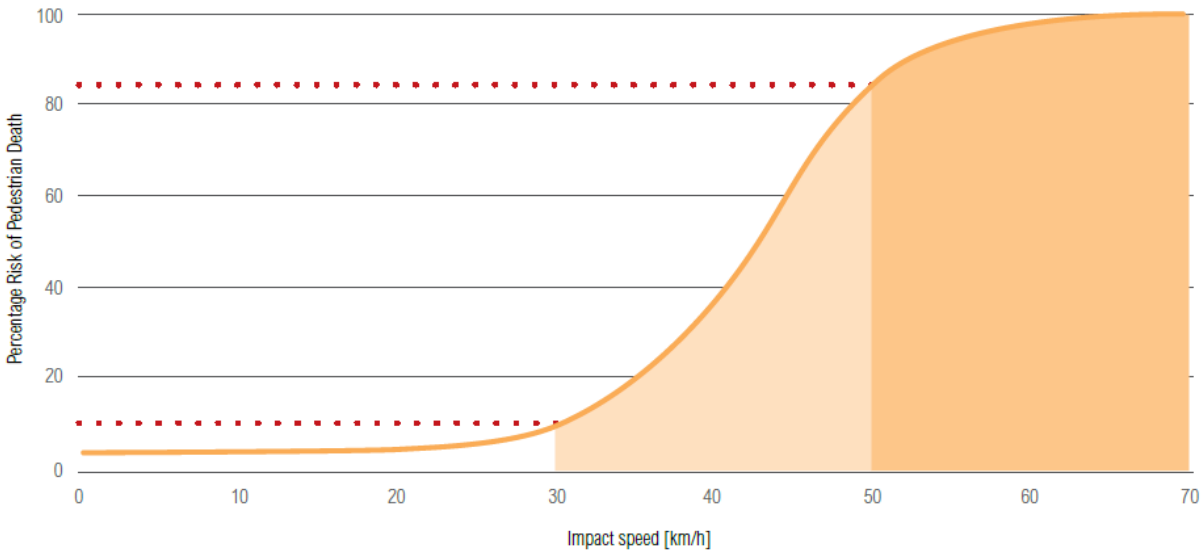
Speed differential is a major challenge to the successful integration of different roadway users in this environment. Reducing the variance offers multiple benefits particularly in terms of public safety. However, this benefit must be assessed against the cost, practicality, and negative implications (i.e. increase in travel time) of achieving this objective to ensure alignment with overarching City policy.

2.3 Effects of Reducing Vehicle Speeds

The following organizations (and others) have studied the effects of reducing vehicle speeds on the safety of pedestrians, the most vulnerable road users:

- The **World Health Organization** *Global Status Report on Road Safety 2018*[1] notes that managing speed effectively and enacting proper speed laws are important to the safety of pedestrians. According to the review, the three best practices for fostering road safety are:
    - Enacting a national speed limit law;
    - Setting urban speed limits not exceeding 50 km/h, with lower limits of 30 km/h recommended for residential and high pedestrian activity areas; and
    - Giving local authorities the power to modify speed limits.

- The **World Resources Institute** *Cities Safer by Design*[2] explains that the fatality risk for pedestrians can be reduced significantly by lowering vehicle speeds. **Figure 1** illustrates the pedestrian fatality risk in relation to the impact speed of the vehicle. According to the figure, a pedestrian has approximately 80-85% risk of death when struck by a vehicle travelling at 50 km/h. Lowering speeds to 40 km/h decreases the risk to 35-40%, which is about half the probability of fatality for a pedestrian struck by a vehicle travelling at the higher speed. Decreasing speed to 30 km/h drops the risk even further to about 10-15%, which is approximately five times lower than the fatality risk at 50 km/h.



Note: The above figure shows the relationship between pedestrian fatalities and vehicle impact speed published by the OECD (2006). Some recent studies show a similar relationship, but account for sample bias to find slightly lower risks in the 40 to 50 km/hr range. (Rosen & Sander 2009, Tefft 2011, Richards 2010, Hannawald and Kauer 2004) There are not, however, studies from low- and middle-income countries where things like vehicle type, emergency response time and other characteristics may influence this relationship. In any case, there is clear evidence to support policies and practices that lower vehicle speeds to 30 km/hr where pedestrians are commonly present, and no more than 50 km/hr on non-grade separated streets.

Figure 1: Pedestrian Fatality Risk and Vehicle Impact Speed (Source: *Cities Safer by Design*)

- The **International Transport Forum** publication *Speed and Crash Risk*[3] found the risk of death to be about four to five times higher in a collision between a car and a pedestrian at 50 km/h compared to the same type of crash at 30 km/h.
- The **AAA Foundation for Traffic Safety** publication *Impact Speed and a Pedestrian's Risk of Severe Injury or Death*[4] found the average risk of severe injury for a pedestrian struck by a vehicle reaches 10% at an impact speed of 26 km/h, 25% at 37 km/h, and 50% at 50 km/h. Similarly, the average risk of death reaches 10% at 37 km/h and 25% at 51 km/h.
- The **Federal Highway Administration** publication *Integrating Speed Management within Roadway Departure, Intersections, and Pedestrian and Bicyclist Safety Focus Areas*[5] notes speeding contributes to nearly one-third of all roadway fatalities and travel speed greatly influences the severity of pedestrian crashes. The average risk of death for pedestrians at impact increases from 10% at 37 km/h to 90% at 93 km/h.

2.4 European Experience with Reduced Speed Limits on City Streets

The **European Union** publication *Speed and Speed Management*[6] concluded that speed is a central issue in road safety in Europe, with speed found to be major contributory factor in around 10% of all collisions and 30% of fatalities. Both excess speed (exceeding the posted speed limit) and inappropriate speed (faster than the prevailing conditions allow) are important causation factors. In addition, speed generally has a negative effect on the environment, but a positive effect on travel time. The negative effects are mainly a societal problem and are hardly noticed by individual drivers. Individual drivers on the other hand particularly notice the positive effects.

The following sections summarize the more salient aspects of the report concerning reduced speed limits on City streets in Europe:

Speed Choice

Speed choice is affected by the characteristics of the driver, by factors related to human perceptual skills and limitations, by the characteristics of the road and the road environment, and by the characteristics of the vehicle.

According to a 2003 survey, around 20% of European motorists report driving a little faster or much faster than other drivers. At the same time, only around 5% state that they drive more dangerously than other drivers. Apparently, dangerous driving is not related to speed in the mind of most of these drivers.

There is no single solution to the problem of excess and inappropriate speed. The following steps are important:

1. Setting speed limits
2. Information about the speed limit (signs and road markings, some vehicles have in-vehicle displays)
3. Road engineering measures (speed humps, road narrowing, roundabouts)
4. Police enforcement to control the intentional speeder

All steps should be accompanied by information to the driver on the problem of speed and speeding, what the speed limit system is based on and why, what additional measures are taken and why, and preferably also on the (positive) outcomes of these measures.

Setting Appropriate Speed Limits

The Vision Zero approach to setting appropriate speed limits is becoming more common in Europe. It places an upper limit on the injury risk that could occur on the road, virtually eliminating the chance of a fatality occurring. The speed limit and the design of the road infrastructure would then be matched to ensure that the injury risk was not exceeded.

Design speed should be consistent over a longer stretch of road. A substantial reduction at a specific location must be supported by more than just a sign with the lower speed limit. Additional warning signs should be accompanied by a change in road design and/or pavement markings in these locations.

Transitions from one speed limit to another should be accompanied by a change in the road or road environment characteristics.

Roadway Engineering

Physical speed reduction measures are often necessary in residential areas, at-grade intersections at main urban and rural roads, high speed to low speed transition zones, and midblock pedestrian crossings. Of these measures, roundabouts can be expected to reduce the number of injury collisions by 40 to 50%. The effect on fatal collisions is even larger.

At midblock pedestrian crossings, the speed of motorized vehicles should be kept low. A raised crossing will make high speeds less likely.

Speed Enforcement

Speed enforcement is an essential speed management measure if the problem is not solved in a structural way by road design, engineering measures, or in-vehicle technology.

Education and Publicity Campaigns

The direct effect of publicity campaigns on speed behaviour is typically limited. The research found a 16% reduction in speeding on average. Most effective were local campaigns in combination with enforcement. Achieving a feeling of intimacy and immediacy through these types of local initiatives increases the effect of a campaign.

The effect of mass media campaigns (i.e. television, radio, or newspaper as the communication channel) was not significant. When using these campaigns, a convincing, emotional approach was found to be more effective than a rational, informative approach.

Some European countries mandate driver improvement courses in response to speeding offenses (i.e. take the course to prevent/reduce demerit points). The practice has been implemented in Austria, Switzerland, Finland, UK, and Belgium. Follow-up studies found the effects of this program small or non-existent.

2.5 Speed Limit Regulations

Speed regulations aid motorists in selecting operating speeds that are safe for the prevailing conditions. The maximum safe speed at any location will vary as road geometry, traffic demands and road environment change.

The selection of a posted speed limit for a specific location must consider legislative regulations, public recognition and understanding, ease of implementation, capital and maintenance costs, and recognized engineering standards and practices, which aid in achieving consistency in application. In Ontario, the *Highway Traffic Act* (HTA) provides the regulatory basis for establishing rates of speed on roads. Per Section 128 (1)(a) of the HTA, the statutory, or defacto, speed limit on roads within local municipalities is 50 km/h[7]. The Act permits municipal councils to prescribe different rates of speed (less than 100 km/h) on roads under their jurisdiction by by-law.

Under Regulation 615 of the HTA, speed control signs (MAXIMUM SPEED) must be installed on all streets with a maximum limit differing from the 50 km/h statutory rate of speed. In neighbourhoods with many streets featuring a 40 km/h (or lower) speed limit, this requirement necessitates the installation and maintenance of an excessive number of signs and potentially inconsistent applications. In part to address this concern, the Province enacted Bill 65 on May 1, 2018, enabling municipalities to designate

areas where they can impose speed limits lower than 50 km/h. Per subsection 128 (2.1) of the HTA, this limit applies to all roads within the area prescribed by by-law without the need to post speed control signs on each street. The MAXIMUM SPEED signs are instead installed on each road entering the designated area at the boundary. This legislation thus provides the regulatory mechanism for establishing area-wide speed limit zones.

2.6 Recommended Practices for Establishing Speed Limits

Road safety can be enhanced by posting credible and realistic speed limits that match the expectation of drivers for a given roadway and its surrounding area. The methodology used for setting speed limits should be systematic, consistent, and repeatable and result in speed limits that:

- Are related to collision risk in favourable conditions;
- Provide a reasonable basis for enforcement; and
- Are fair in the context of traffic law.[8]

Although it is universally accepted that speed limits are first and foremost a tool for safety, the techniques used for setting maximum limits are wide and varied, with the approaches categorized into four groups: engineering (further divided into operating speed and road risk methods), expert systems, optimization, and safe systems. Engineering approaches to setting speed limits are the most widely used but feature the most variants.

The current national approach to setting speed limits is outlined in the Transportation Association of Canada (TAC) publication *Canadian Guidelines for Establishing Posted Speed Limits*[9]. The TAC guidelines, which employ an engineering approach based on road risk techniques, provide an evaluation tool to objectively assess appropriate posted speed limits based primarily on the classification, function, and physical characteristics of a roadway. The risks associated with these engineering factors determine the appropriate limit. The higher the level of risk, the lower the recommended posted speed limit. Many municipalities have adopted these guidelines to determine appropriate limits on their roadways.

The TAC document includes an automated data sheet that considers roadway geometry, pavement width, roadside hazards, pedestrian and cyclist exposure, number of intersections, and on-street parking. When the required data is entered into the spreadsheet, a recommended posted speed limit is provided consistent with the roadways' physical characteristics.

3 Existing Conditions in the City of Waterloo

3.1 Approach to Setting Speed Limits

Per the HTA, the defacto (unposted) speed limit in the City of Waterloo is 50 km/h. Schedule 17 of the City's Traffic By-law 08-077[10] describes roadways with speed limits that differ from the statutory rate.

The City considers requests for lower speed limits on an ad-hoc basis, applying industry standard guidelines and recommended practices in assessing potential locations. Along with good engineering judgement, the City uses the methodology from the TAC *Canadian Guidelines for Establishing Posted Speed Limits* in establishing posted speed limits on roads under its jurisdiction.

3.2 40 km/h Speed Limits in School Zones

In response to a growing number of school zone speeding complaints from community groups and residents, City Council authorized a pilot project in July 2003 to study the effects of 40 km/h speed limits in school zones. The study concluded that reduced speed limits did not lower operating speeds in the pilot area school zones to within legal limits. Although speeds were reduced, the observed decrease typically matched the reduction in speed limit and remained 10 to 20 km/h above the posted limit. Considering the results, City staff recommended efforts be steered toward reducing congestion around schools, conducting driver education for speeding, and promoting programs that continue to teach children proper crossing procedures instead of expanding the pilot project.

In 2011, City Council approved a subsequent program to establish 40 km/h speed zones at all elementary schools in Waterloo[11]. The enabling speed control signs were implemented over a two-year period, beginning with the following five schools in May 2012:

- Laurelwood Public School (on Brentcliffe Drive);
- Cedarbrae Public School (on Cedarbrae Avenue);
- Mary Johnston Public School (on Keats Way);
- Elizabeth Ziegler Public School (on Moore Avenue); and
- Sandowne Public School (on Sandowne Drive).

Speed surveys in fall 2012 showed reductions on roads at two of the five schools but speeds still exceeded the 40 km/h limit with 85th percentile speeds closer to 50 km/h.

The City completed the program in spring 2013, installing 40 km/h speed zones at the 16 remaining elementary schools in Waterloo.

Through the different initiatives, City staff have monitored vehicular speeds in school zones. **Figure 2** summarizes the average speed and average 85th percentile speed observed before and after the City installed 40 km/h speed signs in 19 of the school zones. As observed with previous monitoring for the pilot projects, the reduced speed limits did not effectively lower vehicle operating speeds to the posted limit. While there were measurable improvements, average 85th percentile speeds remained between 2 km/h and 22 km/h above the signed limit. Additionally, at five locations both the average and 85th percentile speeds increased.

The City's speed monitoring has illustrated the installation of 40 km/h speed limit signs in the absence of traffic calming measures and/or increased enforcement does not appear to significantly modify driver behaviour and achieve compliance.

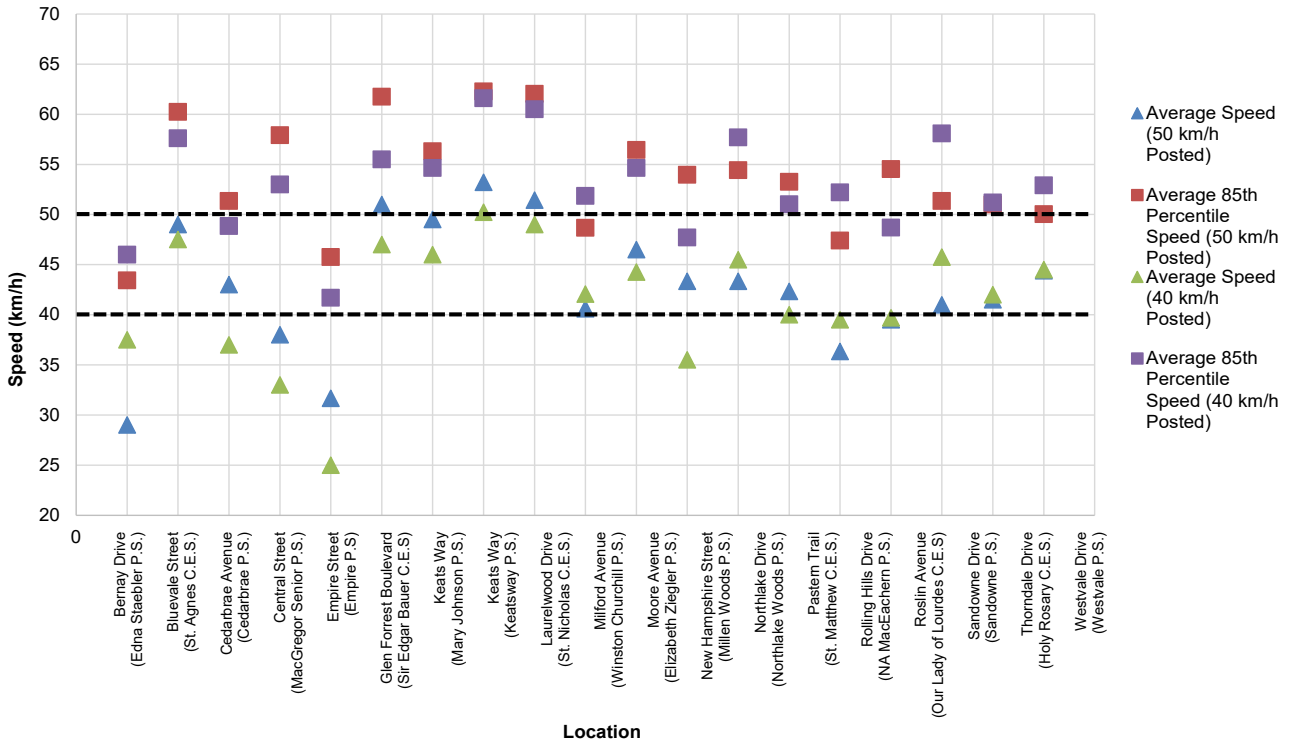


Figure 2: Observed Change in Vehicle Operating Speeds in School Zones

3.3 Public Opinion on Reducing Speed Limits on Residential Streets

As part of the JSIC neighbourhood speed limit review, the City posted a six-question survey to its Engage Waterloo[1] portal in early 2019 to gauge public opinion on lowering posted speed limits to 40 km/h. The survey attracted 308 respondents, the majority of which (76%) were aged 30 to 54 years. Other participants ranged in age from 55 to 64 (11%), 19 to 29 (8%), and 65 and above (4%). The remaining respondents were under 18.

In terms of travel modes, 74% of respondents indicated they use a motor vehicle daily and generally walk on a daily or weekly basis (68%). Cycling use varied by respondent, evenly spread between never, rarely, sometimes, weekly, and daily. Most respondents rarely or never use transit (79%).

When asked about vehicle speeds:

- Most respondents agreed or strongly agreed (75%) that lowering traffic speeds is a priority in their neighbourhood. About 20% of respondents disagree or strongly disagree, while the remaining 5% were neutral or not sure if lowering traffic speeds is a priority in their neighbourhood (**Figure 3**).

[1] https://www.engagewr.ca/waterloo

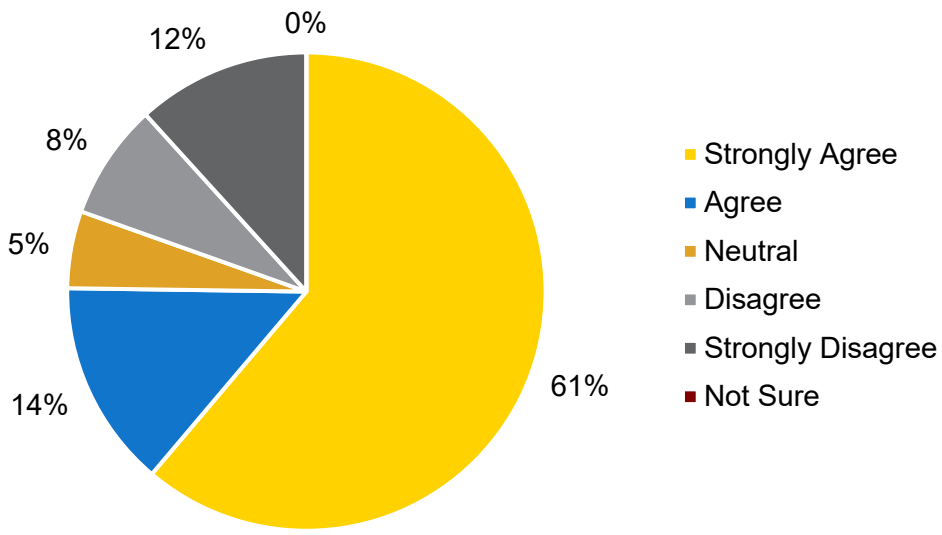


Figure 3: Lowering Traffic Speeds is a Priority

- Respondents indicated 40 km/h posted speed limits should be implemented (**Figure 4**):
    - On residential neighbourhood roads (73% of respondents);
    - On commonly used school routes (71%);
    - In pedestrian shopping and marketing areas (53%);
    - On cycling routes (43%); and
    - At other locations (5%) including roads in Uptown Waterloo and roads with a history of collisions. Some felt school speed limits should be reduced to 30 km/h and more enforcement was required.

  Only 11% of respondents indicated 40 km/h speed limits were not required on any roads.
- Most respondents (74%) felt reducing the speed limit from 50 km/h to 40 km/h in residential neighbourhoods was acceptable.

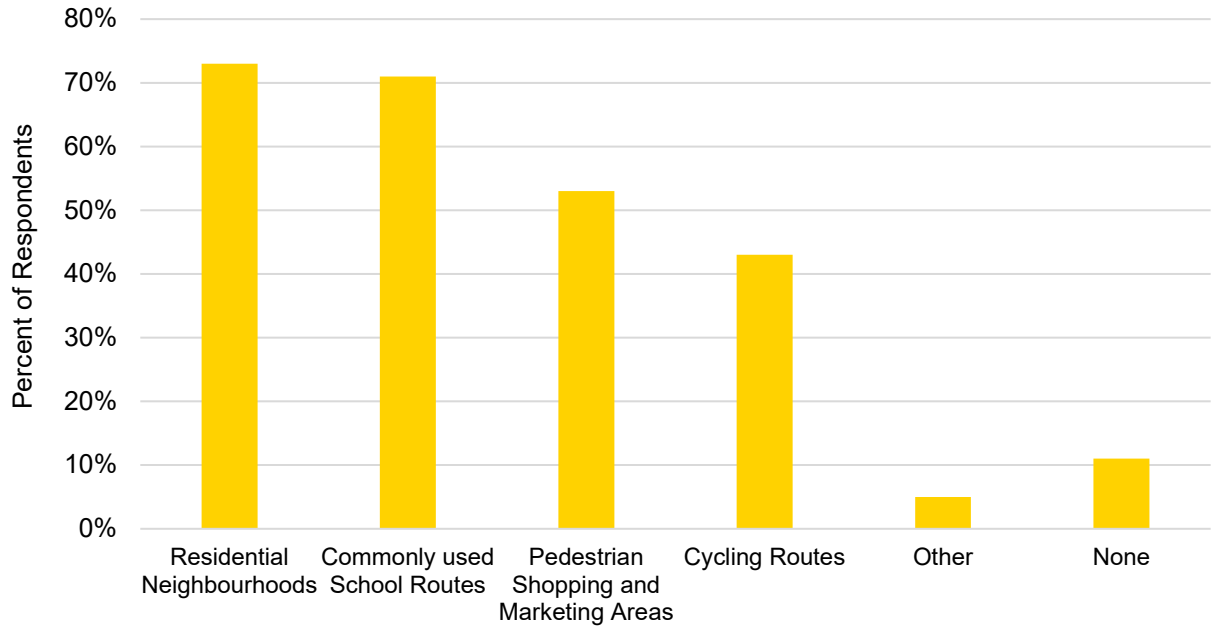


Figure 4: Locations to Implement 40 km/h Speed Limits

3.4 Recent City Council Directions

In addition to the JSIC neighbourhood speed limit review, City Council has expressed its desire to realize lower speeds on City streets through several initiatives over the past few years:

- The *City of Waterloo 2019-2022 Strategic Plan* approved by City Council on June 24, 2019 establishes "safe, sustainable transportation" as a strategic pillar (or area of focus) for the municipality. "Safe, sustainable transportation exists when all users and all modes of transportation are able to share roadways and trail systems safely; **when traffic speeds respect the safety of the community** *(emphasis added)*; when policy and planning supports the development and maintenance of sustainable infrastructure; and when more residents are able to rely on sustainable modes of transportation such as public transit or active transportation to get where they need to go".[12]
- In response to the COVID-19 pandemic, City Council directed staff in May 2020 to assess opportunities to quickly and affordably expand active transportation infrastructure to facilitate essential trips and provide more equitable access to safe, green spaces for physical activity while permitting physical distancing. As part of this initiative, City Council approved changes to Traffic and Parking By-law 08-77 in June 2020 to establish two 40 km/h streets. Additionally, Council directed staff to consider specific "slow streets", 40 km/h area-wide speed zones, and 30 km/h speed zones near schools.
- During all three presentations to Council through this study, Council members reiterated their expectation for the TMP Update to include policy direction and other initiatives aimed at reducing speeds on neighbourhood streets to at least 40 km/h in neighbourhoods and 30 km/h in school zones.

4 Review of Comparable Cities

4.1 Area-Wide Speed Limit Reductions

Several Canadian municipalities have implemented or are considering area-wide speed limit reductions. Most jurisdictions have decided to proceed cautiously with the initiative, beginning with a pilot project or some other form of trial with a 40 km/h (or in some cases 30 km/h) speed limit to allow time to gauge the potential benefits and consequences before full scale implementation. Others, such as the City of Hamilton, have chosen to proceed with area-wide reductions without an assessment period.

Table 1 summarizes the experience of other Canadian municipalities with area-wide speed limit reductions. The subject jurisdictions were identified through an on-line search completed in May 2020. Like Waterloo, the municipalities include both mature and developing residential communities.

Several municipalities are still in the process of evaluating the permanent implementation of reduced speed limits on an area-wide basis. Some municipalities have evaluated a speed limit reduction on limited road sections which showed minimal impact on reducing operating speeds. The impacts of reducing speed limits on a neighbourhood-wide scale have not yet been evaluated in other Canadian municipalities.

Table 1: Experience of Canadian Municipalities with Area-Wide Speed Limit Reductions

Municipality	Description and Status

City of Calgary[13]	• Considering three residential speed limit scenarios:
	  ○ Unposted speed limit of 30 km/h on both residential and collector streets;
	  ○ Unposted speed limit of 30 km/h on residential streets with collectors posted at 50 km/h; and
	  ○ Unposted speed limit of 40 km/h on both residential and collector streets.
	• Planned to seek public feedback on the alternatives in early 2020, but funding for engagement was reallocated to another program during budget deliberations.
	• Continuing to analyze the three scenarios and will be providing a recommendation to the City's Standing Policy Committee on Transit and Transportation in fall 2020.

Table 1: Experience of Canadian Municipalities with Area-Wide Speed Limit Reductions

Municipality	Description and Status
City of Edmonton[14]	• Reduced speed limits from 50 km/h to 40 km/h in six neighbourhoods for six months in 2010. Three neighbourhoods retained the 40 km/h speed limit after post-implementation monitoring. • Adopted a Speed Reduction Policy in 2013 that allows residents to request the City to review lowering a residential speed limit to 40 km/h; and • Endorsed a default speed limit of 40 km/h for residential roads throughout Edmonton and a 40 km/h speed limit for Jasper Avenue, Whyte Avenue, and several high pedestrian areas in March 2020. The change is expected to take effect late summer or early fall 2021 after modifications to the City's traffic by-law.
City of Hamilton[15]	• Installed 40km/h signs on over 250 local residential streets starting in 2015. Signs are installed in school zones and on neighbourhood streets on a street by street basis in response to resident requests. • In July 2019, Hamilton City Council approved a plan to identify and sign all neighbourhoods within the City with a 40 km/h speed limit, and all school zones at 30 km/h. The reduced speed limits will apply to local and minor collector roads within the designated areas. The total estimated cost for implementation, city-wide, is $2,500,000 over three years.
City of London[16]	• Implemented an area speed limit or a 40 km/h default speed limit on local streets in October 2019. Area speed limit zones will also be designated as Community Safety Zones. • Investigating the applicability of 40 km/h speed limits to collector and arterial roads in the downtown area, as well as the reduction of speed limits from 40 km/h to 30 km/h on local streets in School Zones.
City of Mississauga[17]	• Adopted recommendation in June 2019 to implement 40 km/h Neighbourhood Area Speed Limits. Currently implementing in 11 neighbourhoods across Mississauga.
City of Ottawa[18]	• Designated 12 Community Safety Zones in ten different Wards. Eight of the 12 zones have a 40 km/h speed limit. • Passed a by-law to allow the General Manager of Transportation Services to designate areas in accordance with the "Speed Zoning Policy", with speed limits becoming legally enforceable once gateway signs are erected. The City has not reported the findings yet.

Table 1: Experience of Canadian Municipalities with Area-Wide Speed Limit Reductions

Municipality	Description and Status
City of Toronto[19]	• Reduced speed limits by 10 km/h on approximately 250 kilometres of roads (from 70 km/h to 60 km/h, 60 km/h to 50 km/h, and 50 km/h to 40 km/h). • Introduced a holistic speed management strategy in the City's Vision Zero 2.0 – Road Safety Plan Update in 2019. The strategy includes a recommendation to lower residential local road speed limits to 30 km/h. Implementation is proposed to occur on a ward by ward basis over five years starting in 2021.
City of Vancouver[20]	• Implemented 30 km/h speed limits on designated bike routes and in school and playground zones during posted times and on local streets. • Designated portions of Hastings Street, 29th Avenue and Victoria Drive with a 30 km/h speed limit. • Directed by City Council in May 2019 to identify a local street, area, or areas within the City to pilot a 30 km/h speed limit demonstration project focused on mixed mode use, reduced speeds, and complimentary road design, with a mechanism to record and analyze before and after data. Staff were asked to report back to Council with an implementation strategy, timing, and budget as well as proposed road design changes by Q3 2019. No further record found on the City's website.

4.2 City of Kitchener Neighbourhood Speed Limit Review

As part of the JSIC neighbourhood speed limit review, in 2019, the City of Kitchener reviewed resident feedback and the benefits and challenges of reduced speed limits in Kitchener's residential neighbourhoods[21]. Based on the review, City Council authorized the Neighbourhood Speed Limit Review pilot project to investigate impacts, challenges, and costs associated with future implementation across the City on a permanent basis.

The year long pilot project began in November 2019. The City has selected three primarily residential areas for the trial. Through "gateway" signs at entry and exit points, road users are informed of the default 40 km/h speed limit within the designated Neighbourhood Speed Limit Pilot Areas. Speed limits in school zones within the pilot project areas have been further reduced to 30 km/h and signed accordingly. The City is collecting data during the pilot and will report evaluation results and recommendations to Council in fall 2020.

As part of the pilot project, the City is undertaking several initiatives to engage and educate the public about speeding. Communication with the public is City-wide, but with focused effort in the Neighbourhood Speed Limit Pilot Areas and surrounding communities. Specific outreach initiatives include:

- Social media posts on City accounts, included geo-targeted posts for Neighbourhood Speed Limit Pilot Areas;
- Pamphlets and posters at City-run facilities;
- Direct mailings to residents within the pilot project areas;
- Notifications sent home with students from local schools; and
- Webpage for information, updates, and ongoing feedback.

5 Recommended Approach

5.1 Area-Wide Speed Limits in Residential Neighbourhoods

As previously noted, speed regulations are defined in the HTA, which states “no person shall drive a motor vehicle at a rate of speed greater than 50 km/h on a highway within a local municipality or within a built-up area.” This speed limit is commonly known as the Statutory Speed Limit.

Studies have shown that a reduction in vehicle operating speeds from 50 km/h to 40 km/h increases the chance of survival from 15% to 70% for a vulnerable road user struck by a vehicle. This rate is further increased to 90% for operating speeds of 30 km/h[22].

Consistent with this direction, the provincial government amended the HTA as part of the *Safer School Zones Act, 2017* to allow municipalities to designate an entire area with a posted speed limit lower than 50 km/h. Prior to this amendment, speed limit signs had to be posted for the complete length of each roadway with a reduced speed limit. But now a municipality is only required to post the Gateway Speed Limit Signs shown in **Figure 5** at entrance and exit points to the designated area. All streets that fall within the posted signs are then designated with the same speed limit denoted on the gateway signs.

Figure 5: Gateway Speed Limit Signs

Area-wide speed limit reductions are not yet common in Ontario municipalities comparable to Waterloo although several are currently considering this approach. Even where a jurisdiction has taken this approach, analysis findings are not yet available, making it difficult to reliably assess the merit of implementing such measures in Waterloo. From the City’s experience in reducing speed limits in school zones, follow-up field surveys indicated speeds tended to diminish but remained above the 40 km/h

posted limit. Sufficient data was not available to assess the sustained, long-term effect of these lower speed limits.

Consistent with its philosophy on Vision Zero, City Council has expressed a strong desire to realize lower vehicle speeds in the City, specifically for safety reasons on neighbourhood streets and especially around schools. But as previously noted, installing signs alone rarely achieves compliance with lower posted limits and sustained long-term change in vehicle operating speeds. For this reason, the City should develop a comprehensive Speed Management Program in concert with a policy of area-wide 40 km/h speed limits on neighbourhood streets and 30 km/h speed limits in school zones. Building on the City's current pilot in the Westvale and Eastbridge neighbourhoods, the program should focus primarily on speed management for local and collector roads within its residential communities. Most higher order roads in the City fall under the jurisdiction of the Region of Waterloo or Ministry of Transportation, with the few remaining arterial facilities under City control intended to facilitate the movement of large volumes of people, including truck traffic, at higher speeds.

5.2 Potential Issues and Challenges

It is important to uniformly implement the area-wide speed limit in each neighbourhood to provide a consistent message. The new signing should be prominently located and clear to motorists. Additional signage in areas where drivers may be prone to speeding can help emphasize the speed limit. Any outdated signs should be removed to avoid motorist confusion and signage clutter.

Simply lowering the speed limit does not guarantee motorists will drive slower. As noted in the research above, lower speed limits are more effective when combined with enforcement and education. Speed management countermeasures (typically physical) may also have to be implemented along the roadway.

Table 2 summarizes several potential challenges that may result from reducing neighbourhood speed limits to 40 km/h. Most issues listed below can be mitigated through proper implementation, consulting with the public and external agencies, monitoring, and adequate enforcement.

Table 2: Potential Challenges of Lowering Speed Limits

Challenge	Details
Non-Compliance	• Drivers are more likely to drive according to the geometric design of the road rather than the posted speed limit, especially areas where the speed limit used to be higher. • Posted speed limits not matching the physical and geometric characteristics of the roadway frustrate motorists and may foster aggressive driving habits. • Lowering the speed limit without adequate enforcement and education can increase the rate of non-compliance.

Table 2: Potential Challenges of Lowering Speed Limits

Challenge	Details
Public Confusion	• Lower posted speeds may confuse non-residents travelling in the area. Low speeds can cause confusion for non-residents travelling in the area. • Lack of consistency with other municipalities may create confusion for road users.
False Sense of Security	• Lower posted speed limits may create a false sense of security for cyclists and pedestrians if vehicle operating speeds remain high.
Adjustment of Transit Service Schedules	• Changes to public transit schedules may be required to account for the speed limit reduction.
Enforcement	• Feedback from the survey mentioned in **Section 3.3** indicated that enforcement issues could be a challenge. • Lack of enforcement may result in non-compliance.
Emergency Response Times	• Lower posted speed limits may impact response times for emergency services.

Some Canadian communities have explored broader City-wide speed limit reductions to 40 km/h (and even 30 km/h). This approach is not recommended for Waterloo for several reasons:

- Its unlikely Regional Roads will be posted at 40 km/h resulting in inconsistencies;
- Capacity and traffic control system impacts of operating heavy volume arterial roads at 40 km/h;
- Potential for neighbourhood traffic shortcutting if arterials become more congested;
- Increased impacts to public transit schedules and headways; and
- Greater emergency response times.

6 Impacts on Capital, Maintenance, and Operating Practices

New speed limit signs will be required to implement the area-wide 40 km/h speed limits. The estimated cost to sign each designated area is $10,000, inclusive of manufacturing, installation, and removal. An additional $20,000 is recommended for outreach initiatives to inform and educate residents of the speed limit changes.

The existing GIS sign database and inventory used by the City should be updated to ensure on-going maintenance is documented.

7 Benefits Statement

Table 3 summarizes the potential benefits of lowering speed limits in residential neighbourhoods. Reduced vehicle speeds, improved road safety and greater active transportation use support the City's strategic pillar of safe, sustainable transportation.

Table 3: Potential Benefits of Lowering Speed Limits

Benefit	Details
Increased Survival Rate	• The likelihood of survival for a pedestrian struck by a vehicle is more than double if the vehicle is traveling 30 km/h rather than 40 km/h and nearly five times greater if the vehicle is traveling 30 km/h rather than 50 km/h.
Decreased Risk of a Collision	• Lower operating speeds decrease stopping distance required to prevent a collision. • Drivers traveling at lower speeds are better able to process moving pedestrians and objects. • Opportunities for eye contact between road users increases.
Increased Health Benefits	• A safer environment for active transportation users is provided. • Facilitating active travel reduces the instances and severity of health-related issues such as cardiovascular diseases, diabetes, and some cancers.
Increased Human Interactions	• Increased active transportation provides more opportunities for interaction between residents and promotes a sense of community. • Slower vehicle speeds can create more welcoming and safer environments for pedestrians.
Reduced Confusion in Nearby Municipalities	• The City of Kitchener is currently conducing a pilot project assessing 40 km/h neighbourhood speed limits. Introducing a reduced residential neighbourhood speed limit would alleviate potential confusion for road users who travel to and from Kitchener.

8 References

1 World Health Organization. *Global Status Report on Road Safety 2018*. 2018. p. 28.

2 World Resources Institute. *Cities Safer by Design: Guidance and Examples to Promote Traffic Safety through Urban and Street Design*. July 2015, p. 15.

3 International Transport Forum – International Traffic Safety Data and Analysis Group. *Speed and Crash Risk*. 29 March 2018. p. 14-15.

4 AAA Foundation for Traffic Safety. *Impact Speed and a Pedestrian's Risk of Severe Injury or Death.* September 2011. p. 1.

5 Federal Highways Administration. *Integrating Speed Management within Roadway Departure, Intersections, and Pedestrian and Bicyclist Safety Focus Areas.* April 2016. p. 5.

6 European Commission. *Speed and Speed Management.* European Commission, Directorate General for Transport. February 2018.

7 Queen's Printer for Ontario. *Highway Traffic Act, R.S.O. 1900, c. H.8.* January 2020. Part IX, Section 128.

8 Transportation Association of Canada. *Speed Management Guide*. February 2016.

9 Transportation Association of Canada. *Canadian Guidelines for Establishing Posted Speed Limits.* December 2009.

10 City of Waterloo. *Traffic By-law 08-077.* 13 August 2018. p.17.

11 City of Waterloo. *Council Meeting Agenda.* 22 April 2019. p. 27.

12 City of Waterloo. *City of Waterloo 2019-2022 Strategic Plan Report*. p. 10. July 2019.

13 City of Calgary. *Street Safety and Neighbourhood Speed Limits Update – TT2019-1300.* 23 October 2019.

14 City of Edmonton. *Residential Speed Limits: Increasing Safety and Livability in Edmonton's Neighbourhoods – City Operations Report CR-7769.* 26 February 2020.

15 City of Hamilton. *Bill 65 – Neighbourhood Speed Limit Reduction Implementation (PW19058) (City Wide).* 17 June 2019.

16 City of London. *Council Minutes.* 1 October 2019.

17 City of Mississauga. *General Committee Agenda.* 02 October 2019.

18 City of Ottawa. *Gateway Speed Limit Signage in Residential Areas.* 08 August 2018.

19 City of Toronto. *Vision Zero 2.0 – Road Safety Plan Update.* 13 June 2019.

20 City of Vancouver. *Safer Slower Streets: 30 km/h Residential Street Pilot.* 14 May 2019.

21 City of Kitchener. *Neighbourhood Speed Limit Review – Report DSD-19-159.* 12 August 2019.

22 City of Toronto. *Toronto Complete Streets Guidelines*. 2016. Figure 8-5.

13 ADDRESSING IDENTIFIED COLLISION LOCATIONS

Technical Memorandum

Date: November 3, 2020

To: Christopher Hodgson, City of Waterloo

From: Gene Chartier, Paradigm Transportation Solutions Limited

c.c.: Kate Whitfield, Alta Planning + Design
Susan Hall, Lura Consulting

Re: **Addressing Identified Collision Locations**

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1 Introduction

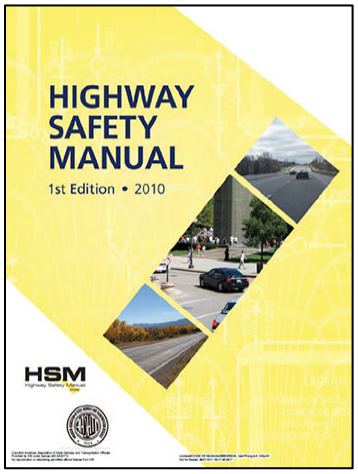
The City of Waterloo prepares an annual report that summarizes and analyzes reported collisions and emerging safety trends on roads within the City over the preceding year(s). Based on data provided by the Waterloo Regional Police Service, the report identifies the intersection, midblock and roundabout locations experiencing the highest number of collisions by ranking and severity. Additionally, the report highlights short and long-term trends, providing comparisons based on several factors such as time of day, day of week, and weather conditions. The report is intended to assist the City make sound investment decisions and evaluate the performance of road safety programs, policies, and strategies.

The City wishes to develop a method to further use the annual collision report details to help justify funding for countermeasures at problem locations. This memorandum establishes a process to review, analyze, design, cost, and implement appropriate countermeasures at the highest ranked locations in Waterloo, which will be incorporated into the **City of Waterloo Transportation Master Plan Update**. The document:

- Summarizes the **state of the practice** in quantitative road safety analysis and assessment;
- Reviews the **experience of other Ontario municipalities** in proactively addressing identified collision locations;
- Outlines past and current initiatives in the City of Waterloo;
- Presents the **recommended approach** for the City to leverage its collision data to help justify funding for countermeasures at priority locations;
- Identifies potential issues and **impacts on capital, operating and maintenance practices** resulting from the countermeasure program; and
- Assesses the potential **benefits**.

2 State of the Practice

2.1 Highway Safety Manual (2010)



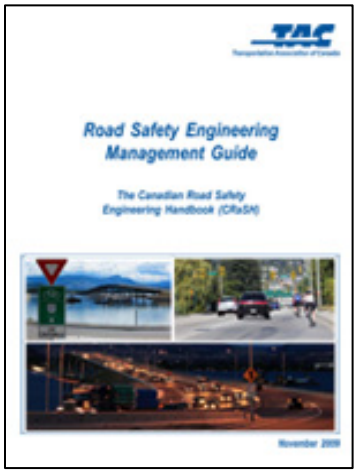
The American Association of State Highway and Transportation Officials' (AASHTO) *Highway Safety Manual* (HSM)[1] is the preeminent guidance document for conducting quantitative road safety analysis. The HSM, first published in 2010, presents contemporary scientific methodologies for estimating roadway safety performance to inform decision-making. The manual includes guidance on:

- Human factors and the fundamentals of traffic safety;
- The Roadway Safety Management Process, including:
  - Network screening (identification of sites with potential for collision or severity reduction);
  - Site assessment (diagnosis, countermeasure selection, economic appraisal);
  - Project prioritization;
  - Safety effectiveness evaluation;
- Predictive methods for infrastructure improvement project alternative analysis and development/design, including:
  - Use of *Safety Performance Functions* (SPFs) (models) developed to predict collisions by severity specific facility types and base conditions; and
  - Associated *Collision Modification Factors* (CMFs) to estimate the potential effects of design alternatives or changes from base conditions.

The HSM emphasizes the use of analytical methods to quantify the safety effects of decisions in roadway planning, design, operations, and maintenance. These tools allow safety features to be evaluated comparably with other quantitative transportation performance measures such as traffic operations, environmental impacts, and construction costs.

The second edition of the guidebook is currently in development and expected to be published in 2022.

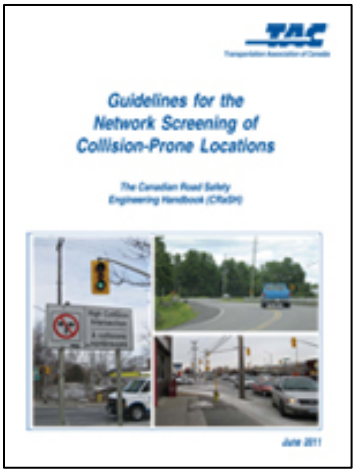
2.2 Road Safety Engineering Management Guide (2009)



The TAC *Road Safety Engineering Management Guide*[2] identifies, defines, and shares good practices in road safety engineering to assist Canadian road authorities and engineering practitioners in servicing the public and addressing road safety issues at the local level. The guidebook, which is the anchor publication of the *Canadian Road Safety Engineering Handbook (CRaSH)* series, presents fundamental concepts and principles related to managing road safety engineering including:

- Defining road safety;
- Identifying industry-accepted measures of road safety and methods of collision data management;
- Describing the basic requirements for managing road safety in an engineering context and linkages to other road safety stakeholders;
- Explaining how road safety engineering can be included at each stage of the project life cycle and the benefits of considering road safety early in the process; and
- Defining good practice in road safety engineering; and
- Recommending a framework to make informed decisions concerning road safety.

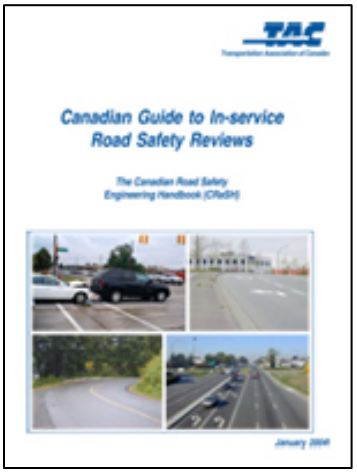
2.3 Guidelines for the Network Screening of Collision-Prone Locations (2011)



The Transportation Association of Canada's (TAC) *Guidelines for the Network Screening of Collision-Prone Locations*[3] recommends analytical procedures and statistical concepts to identify and prioritize locations with the highest potential for safety improvement. The document provides guidance for agencies to select a network screening approach and methods compatible with their current resources and needs, as well as required data and resources to move from interim to advanced methods.

The guidebook, which forms part of the *Canadian Road Safety Engineering Handbook (CRaSH)* series, provides the methodology and implementation steps, such as the development or acquisition of analytical tools, to help determine high-risk locations on a road network where motorists and other road users are killed or seriously injured. Some road authorities undertake scientific investigations such as collision-prone location (CPL) screening activities, black spot programs, or network analysis to determine critical locations. These activities are intended to identify road infrastructure deficiencies and traffic operations and control features that may have contributed to the collisions and establish appropriate mitigation measures.

2.4 Canadian Guide to In-Service Road Safety Reviews (2004)

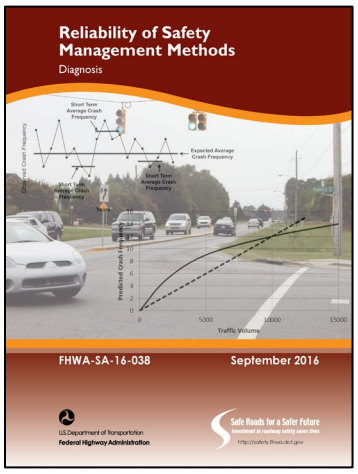


The TAC *Canadian Guide to In-Service Road Safety Reviews*[4] is a practical guide for conducting reviews on existing roads based on best practice experience and expertise from Canada and internationally. The publication provides guidelines on how to upgrade the operational and physical characteristics of existing roads to be more compatible with current traffic conditions and safety knowledge.

The guidebook, which forms part of the *Canadian Road Safety Engineering Handbook (CRaSH)* series, provides information on:

- Safety Management Systems;
- Data Management;
- Network Screening;
- Engineering Analysis;
- Countermeasure Selection; and
- Evaluation of Road Safety Improvements.

2.5 Reliability of Safety Management Methods (2016)



The U.S. Federal Highway Administration (FHWA) publication *Reliability of Safety Management Methods* is a series of five information guides that identify opportunities to employ high-quality data and state-of-the-art (more reliable) analytical methods to support data-driven decision-making throughout the roadway safety management process. The guidebooks describe various methods and the latest tools to support network screening[5], diagnosis[6], countermeasure selection[7], safety effectiveness evaluation[8] and system safety programs[9]. The documents compare traditional methods to more reliable, data-driven ones, which are less susceptible to bias and will likely lead to better-informed decisions, more optimal use of funds, and the implementation of more effective treatments.

3 Experience of Other Ontario Municipalities

3.1 Region of Waterloo

The Region of Waterloo has a long-established road safety program that features a data-driven approach to identifying and prioritizing locations for potential safety improvement[10]. The program also employs an evidence-based approach to countermeasure selection ensuring only measures with a proven track record are considered for implementation.

Road Safety Network Screening Reviews, following the methodology outlined in the HSM, are a fundamental element of the program. The Region uses collision ranking to identify the locations that are highest priority for review and most likely to benefit from countermeasures. The reviews rank approximately 3,500 locations consisting of:

- Intersections of Regional roads;
- Intersections of Regional roads with City/Township roads;
- All signalized intersections;
- Stop-controlled intersections on Regional roads;
- Roundabouts on Regional roads; and
- Midblock segments along Regional roads.

All locations are screened and ranked separately based on motor vehicle, pedestrian, and cyclist collisions.

The Region relies extensively on this collision data analysis in completing/developing:

- Annual Collision Reports;
- Road safety countermeasure programs;
- Focused collision investigations such as ranking by impact type, fatal and injury collisions, etc.;
- Transportation Capital Programs and preliminary designs; and
- Safety-related policies (e.g., roundabout, school zone) and programs (e.g., accessibility enhancements, LED street lighting, pedestrian countdown signals, leading pedestrian intervals).

Of note, the Region of Waterloo has a guideline and typical values for calculating collision costs, SPFs, and CMFs for use in transportation studies.

It is noted the Cities of Kitchener and Cambridge do not have published road safety plans or programs outside traditional traffic calming and speed management initiatives.

3.2 Outside Waterloo Region

Several Ontario municipalities (primarily single and upper-tier jurisdictions) have implemented road safety improvement programs of some form, most recently as Vision Zero (or similar) initiatives. Notable examples include (with the years captured by the road safety plan noted in parentheses):

- City of Hamilton (2019-2025)
- City of Kingston (2019-2024)
- City of London (2014-2019)
- City of Ottawa (2020-2024)
- City of Toronto (2017-2021 + Vision Zero 2.0)
- Region of Peel (2018-2022)
- Region of Durham (2019-2023)

The road safety plans for these municipalities typically include:

- A summary of existing safety programs, policies, and strategies;
- A road safety vision, mission, and goals for the municipality to be achieved through the plan;
- A focus on the “E’s” of safety (enforcement, education, engagement, engineering, evaluation, empathy) in structuring programs;
- About seven to eight target/emphasis areas for safety improvement based on collision history and/or public input (e.g., intersections, distracted/aggressive/impaired driving, young drivers, pedestrians, cyclists, red light running, etc.);
- A series of actions or countermeasures to address each emphasis area; and
- A high-level plan identifying the specific road safety measures to be implemented by year with a cost estimate. Common items include data collection, evaluation, prioritization, and monitoring.

A data-driven approach to identifying, analyzing, assessing, and monitoring locations for road safety improvements is a key feature of the plans. In most cases, the jurisdictions rely on collision data to pinpoint and prioritize sites through network screening and select countermeasures to address identified concerns. Capital works programs for these communities include earmarked road safety initiatives.

4 Past and Current Initiatives in the City of Waterloo

4.1 Collision Data Management and Analysis

The City of Waterloo tracks collisions on its road network in a database application supplied by TES Information Technology[11]. Used by municipalities across Canada, the TES Collision Data Module provides a comprehensive and integrated platform for collision data management and analysis featuring GIS mapping and software tools for:

- Exporting, importing, validating, and manipulating data sets;
- Filtering and sorting individual records;
- Reporting (including the preparation of collision diagrams); and
- Performing basic and advanced safety analysis.

The City uses the collision data stored in TES to:

- Determine a plan of collision reduction measures to address identified needs;
- Review ways that collision frequency can be reduced through engineering measures;
- Justify the need for increased police enforcement;
- Identify individual driver or pedestrian actions responsible for collisions that can be prevented using public education programs;
- Point out a possible need for additional maintenance of streets and traffic control devices;
- Assist in developing a program of signal, sign and pavement marking installations;
- Assist in developing speed zoning, street lighting and sidewalk construction programs;
- Assist in attempts to acquire additional budget funds for promoting an overall traffic collision improvement and safety program in the community; and
- Justify recommendations that necessitate large expenditures or marked changes of a specific street layout.[12]

4.2 Annual Collision Reports

As noted above, the City of Waterloo prepares an annual report summarizing reported collisions and emerging safety trends on City roads using the information stored in its database (typically from the previous three years). The stated purpose of the **Traffic Operations Study – Collision Report Analysis**[13] is to assess the need for intersection improvements based on collision history. More specifically, the report identifies the top (highest rated) intersections (10), midblock sections (5) and roundabout locations (3) and illustrates possible trends. The rankings are based on an Expected Collision System, which rates sites based on:

- Number of collisions;
- Severity of each collision;
- Total number of vehicles entering an intersection/midblock section/roundabout location within a 24-hour period; and
- Number of collisions expected based on an Average Collision Rate for its volume category.

If multiple sites experience the same number of collisions, a severity weighting is used to determine the rank. The severity is determined by applying the following point system:

- 1 point for property damage collisions;
- 3 points for personal injury collisions; and
- 12 points for fatal collisions.

If the number and severity are equal, the difference between the actual and expected number of collisions for the year is calculated. The expected number of collisions is determined from an average collision rate for each AADT category as follows:

$$Expected\ Collisions = (R_i \times AADT \times 365) / 1{,}000{,}000$$

where:

- R_i is the average collision rate for AADT category i (number of collisions per million vehicles entering)
- AADT (Average Annual Daily Traffic) is the most recent traffic volume (vehicles per day)

The City is exploring opportunities to make better use of this information in developing safety countermeasures and capital improvement projects aimed at addressing noted concern.

5 Recommended Approach

5.1 Evolving Towards a More Data-Driven Decision-Making Process

Data-driven decision-making employs evidence-based models that offer agencies the means to quantify and assess safety impacts like other factors such as environmental effects, traffic operations and pavement life. These models provide scientifically sound approaches to identifying locations and roadway features with the highest potential for safety improvement. Based on this information, the agency can then undertake the most beneficial projects with available resources. In using these evidence-based tools, agencies can target investments to reduce collisions on their system with greater confidence.

Through its annual Traffic Operations Study – Collision Report Analysis, the City of Waterloo has endeavored to employ a data-driven approach in establishing road safety priorities. The City's approach to network screening using historical collision data provides rationale for prioritizing locations for improvement but does not reflect the current state of the practice. The program has also not achieved the desired result of justifying funding for needed countermeasures.

As part of a broader strategy aligned with Vision Zero principles (see memorandum), the City should pursue a more formal data-driven decision-making process for its road safety program. As noted in the research, a data-focussed road safety program will help City Council, citizens and other interested parties better understand the nature, causes, and injury outcomes of collisions, providing context for the design of strategies and interventions that will reduce crashes and their consequences. Specific objectives include:

- Targeting funding for countermeasures and other interventions;
- Recommending police enforcement efforts to address specific issues or areas through the ongoing Strategic Traffic Enforcement Program (STEP) and other strategic initiatives;
- Identifying problems and developing resolutions for safety programs;
- Providing a basis for key legislative decisions that impact citizen safety on roadways;
- Identifying high collision locations and making improvements to roadways; and
- Educating the public on safety issues.

The program should incorporate the two approaches to safety management:

- Selecting and treating sites based on site-specific collisions. The **collision-based approach** identifies sites and recommends treatments with the highest potential for site-specific safety improvement. These locations are often referred to as hotspots, blackspots, or sites with potential for improvement. The underlying safety issue typically varies at each site, with the focus not on addressing a defined issue unless the screening is carried out for a specific collision type. Countermeasures can range from relatively simple and low-cost improvements (e.g., enhancing signing or pavement marking, trimming vegetation, or modifying signal phasing) to substantial capital improvement projects (e.g., constructing a roundabout, modifying the skew angle of an intersection, or realigning a horizontal curve). There is an opportunity to achieve reductions in collision frequency and severity at treated locations given the focus on site-specific issues and targeted treatments.

- Selecting and treating sites based on site-specific geometric and operational attributes known to increase collision risk. The **systemic approach** uses this data to identify roadway factors that correlate with specific collision types. Most agencies have traditionally relied on collision history to identify “hot spots” or sites with high crash frequency. However, severe collisions are widely dispersed over road networks, and their location and frequency fluctuate over time. Systemic analysis identifies locations that have the greatest potential to address severe, more impactful collisions, even if there is not a high collision frequency. The City can then proactively apply low-cost countermeasures to those locations. The benefit is wider, but more targeted, safety investment.

The collision-based and systemic approaches are complementary and support a comprehensive approach to safety management, with their primary difference being the way in which the agency identifies issues and develops projects. The systemic approach is more preventative in nature, applying countermeasures to locations with features correlated with collisions but not necessarily having a history of collisions. This distinction is important because the types of collisions occurring on a system remain relatively consistent from year to year while their locations tend to fluctuate, particularly on lower volume roads. It is difficult to address these sites with the collision-based approach due to the low density of crashes and typical data limitations associated with local roads. The systemic approach helps to overcome these limitations by focussing on the underlying risk factors across the network as opposed to collision history at individual locations.

While there are differences in application, both approaches focus on preventing future collisions and reducing fatalities and injuries. Another commonality is concentrating on sites with the greatest potential for safety improvement. In both cases, reliable, data-driven methods are used to inform these

decisions. A predictive approach based on a combination of historical collision, exposure, and roadway data is more reliable than an approach based on crash frequency alone or ad hoc analysis of geometric and operational attributes that may increase risk. Finally, there is not an intrinsic link between the project cost and analysis approach. While systemic projects are generally low-cost and widely implemented, no countermeasures are exclusive to the systemic approach. For example, agencies may install lower unit cost countermeasures at a single site as a standalone low-cost project.

5.2 Implementing a Road Safety Management Process

A data-driven **road safety management** (RSM) process will provide the City with valuable information for system planning, project planning, design and construction, and operations and maintenance of its road network. Safety evaluation develops the evidence-based information used in the RSM process, which can be integrated into the overall project development process as shown in **Figure 1**[14].

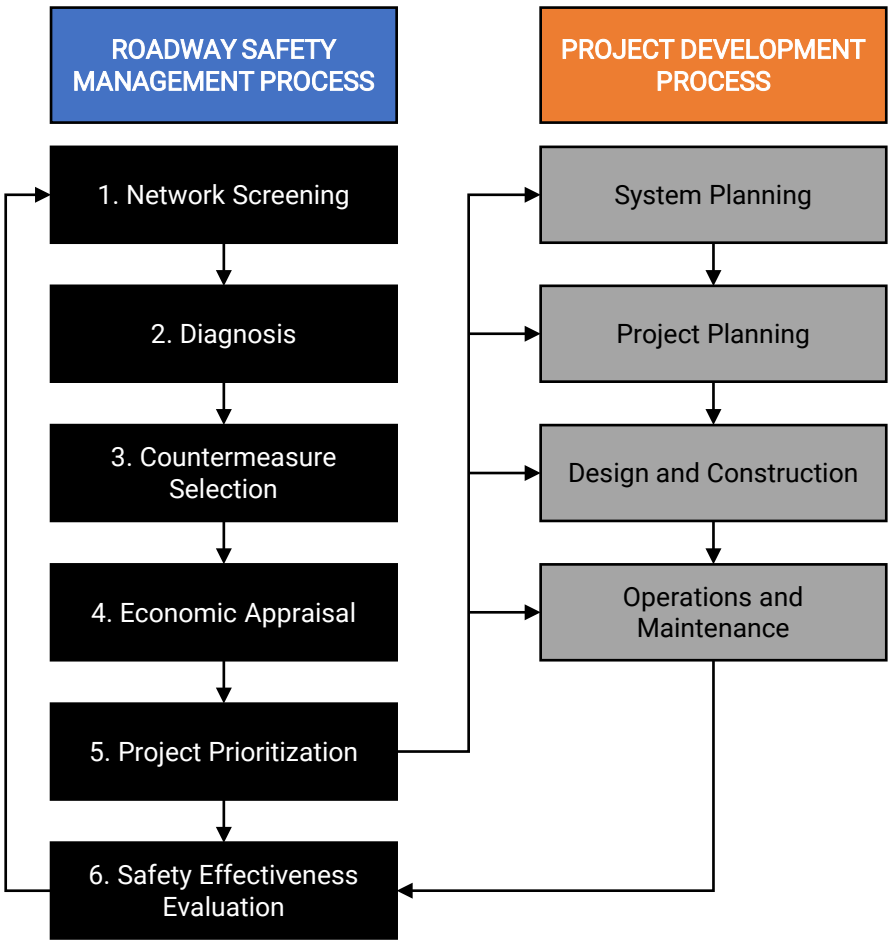


Figure 1 – Integrating the Road Safety Management Process and Project Development Process (Source: *Reliability of Safety Management Methods: Countermeasure Selection*, Figure 2)

The typical RSM process for the collision-based approach shown in **Figure 1** comprises the following six steps. Refer to **Appendix A** for detailed information about the process:

- **Step 1: Network Screening** identifies locations on the road network that could benefit from treatments to improve safety performance (i.e., reduce collision frequency and severity).
- **Step 2: Diagnosis** examines collision experience and contributing factors in further detail. The objectives of this step are to identify trends and patterns based on past reported collisions, assess the collision types and severity levels, and study other elements that characterize the collisions, the environment, the behaviours of drivers and other road users, and the infrastructure elements such as road geometry and traffic control devices. The diagnosis produces a list of contributing factors associated with historical and potential future collisions.
- **Step 3: Countermeasure Selection** develops appropriate countermeasures to target collision contributing factors and reduce collision frequency and severity at identified locations. The countermeasures should directly target the contributing factors, and may include engineering, education, enforcement, and other “E’s”.
- **Step 4: Economic Appraisal** estimates the economic benefit and cost associated with a countermeasure or set of countermeasures. This step involves policy-level decisions such as appropriate collision costs, discount rates, selected economic method, and non-monetary local considerations.
- **Step 5: Project Prioritization** produces a prioritized and optimal list of projects to improve the safety performance (i.e., reduce collision frequency and severity) of the road network, considering available resources. This step involves policy-level decisions such as overall agency goals.
- **Step 6: Safety Effectiveness Evaluation:** Evaluate how a treatment or group of treatments has affected the safety performance (i.e., collision frequency and severity) of the treated locations and the system.

As noted in Section 5.1, the steps for the systemic approach are consistent with the collision-based approach described above. But the steps in the systemic approach occur in a different order, with the first two reversed, being:

1. Identify focus collision types, facility types, and risk factors (Diagnosis); and
2. Screen and prioritize candidate locations (Network Screening).

5.3 Requirements to Enhance Current Capabilities

Advancing a data-driven road safety program requires a comprehensive database of collision records, traffic volumes and geometric characteristics and software applications to store and analyze the information.

5.3.1 Safety Data Management

Collision Records

The City stores historical collision records dating back to 2000 in TES, as noted above. The dataset is complete to the year 2018.

The City should continue to summarize data from Motor Vehicle Collision (MVC) reports in the TES Collision Data Module, at least annually, so safety analyses can be conducted with the most up to date information available. The database should continue to be geocoded to facilitate future data analysis. The collision database contains the following information at a minimum:

- Severity (i.e., fatal, injury, property damage only);
- Impact type (e.g., rear-end, angle, sideswipe);
- Location, time, and date;
- Visibility;
- Environmental condition (e.g., rain, snow, clear);
- Road surface condition (e.g., dry, wet, slush, ice); and
- Road alignment (horizontal and vertical) at the place of collision occurrence.

To achieve a reasonable level of statistical significance, a three to five-year period is typically ideal for conducting a safety evaluation because of the random fluctuations in the data.

The format in which the City's collision data is currently collected and stored is appropriate for collision analysis purposes. It would be ideal to have more recent data available (2018 or later) from the Waterloo Regional Police Service. The City should continue to work collaboratively with the Region of Waterloo and the Ministry of Transportation (MTO) to obtain this collision information on a more regular basis.

Traffic Volumes

The City maintains two sources of traffic volume data:

- Automatic Traffic Recorder (ATR) Counts dating back to 2000, stored in TES
- Turning Movement Counts (TMC) dating back to 2000, stored in TES

The City should continue to conduct a traffic count program. The traffic data is collected in the form of Annual Average Daily Traffic (AADT) for both intersections and road segments. If AADT data is not available, TMC and ATR volumes can be used to estimate AADTs.

For statistical modelling purposes, the major and minor entering AADT volume is typically required to determine the potential safety improvement value for intersections. However, if entering AADT volume is not available, it is possible to estimate the volume based on the total intersections AADTs.

The years of AADT data should correspond to the same period used for the collision data. Similarly, a three to five-year period is ideal for analysis. The AADT volumes are geocoded to facilitate the integration of the different databases for analysis.

Geometric Characteristics

The City does not currently maintain a database of road or intersection geometric characteristics.

The City should compile a geometric characteristics database for all road segments and intersections in collaboration with TES and/or City GIS staff. The geometric characteristics database should preferably be geocoded and include at the very least the following information needed for network screening:

- Road Segment Geometric Characteristics
  - Length of segment;
  - Road classification type; and
  - Number of lanes.
- Intersection Geometric Characteristics
  - Number of approaches;
  - Control type; and
  - Environment.

Other Data

The City should request societal collision cost figures available from the Region of Waterloo and other jurisdictions in Ontario for its safety analyses.

The City should also request SPF and CMF data from the Region of Waterloo and other jurisdictions in Ontario for its safety analyses

5.3.2 Safety Analysis Software

The TES Collision Data Module satisfies requirements for data management and provides necessary functionality for quantitative safety analysis. The City may not be leveraging the full capabilities of the module, which will become necessary if the City moves forward with a data-driven road safety program.

TES also offers a Road Safety Analysis Module that applies the statistical methods contained in the HSM to assist road authorities in ranking problem locations (network screening), diagnosing safety issues, selecting countermeasures to address identified concerns, and conducting economic analysis to determine the preferred measures. The module uses these state-of-the-art methodologies with data from the Collision Data Module to complete, for example:

- Over-representation analysis
- SPF calibration
- Red Light Camera site selection
- Countermeasure selection
- CMF selection
- Costing of countermeasures

The City should acquire the Road Safety Analysis Module and utilize the software for quantitative safety analysis.

Using the software, the City should conduct screening for all collision types possible, provided adequate reliable data exists. Screening may also be done by weighting the expected collision frequency using relative unit cost estimates for collisions of a given severity class (e.g., fatal, serious injury, minor injury, property damage only or no injury).

The City should apply more reliable diagnosis methods than traditional engineering reviews such as structured assessments of collision trends over time and use of tests of proportions and the Haddon Matrix[1] to identify contributing factors and develop targeted countermeasures. These methods are incorporated into software applications like TES.

5.3.3 Training and Program Development

City staff may require additional training on data-driven road safety analysis including:

- The fundamentals of roadway and intersection collision prediction methods; and
- Capabilities and limitations of collision prediction in data-driven safety analysis;

As internal capabilities expand, City staff may require more advanced training and instruction on more advanced quantitative safety topics.

6 Impacts on Capital, Maintenance, and Operating Practices

6.1 Capital

The recommended road safety management process and its various elements provide the foundation for a fundamental shift in how the City plans, prioritizes and implements countermeasures and other safety-related programs. Using data-driven decision-making to identify and prioritize safety improvements will help inform the capital program and bring forward projects designed to reduce collisions and other hazards on City streets.

The City of Waterloo should ensure that safety-driven improvements compete for funding on an equal basis with mobility and state-of-good repair initiatives. Like other jurisdictions, funding for implementing these countermeasures is usually limited; therefore, it is essential that funds are allocated to where it is needed most.

The funds allocated to road safety in the City's budget should focus on the safety improvements recommended through its ongoing road safety management programs, where locations with the most potential for safety improvements should be selected. Through in-service safety reviews, a more detailed analysis, should be conducted for locations identified through network screening as having the highest potential for safety improvement (PSI).

[1] The Haddon Matrix is a tool originally developed for injury prevention but is directly applicable to highway safety in both diagnosis and countermeasure selection.

The City's capital budget could be driven by the result of the detailed safety analysis. For example, top locations identified in the analysis can be allocated for safety improvements in the following year's capital budget.

6.2 Maintenance

A data-driven road safety program provides tools (i.e., collision modification factors and the predictive methods detailed in the HCM and other references) to quantify the effects of maintenance decisions on changes in collision frequency or severity on the transportation system. This information could be extended to a benefit/cost analysis using methods detailed in Section 5 of this memorandum.

6.3 Operations

The move toward data-driven, evidence-based road safety programs will have the greatest impact on traffic operations and active transportation in the City. The City can measure the safety performance of intersections and midblock sections using any one or a combination of the performance measures allowing more nuanced and insightful assessment.

A safety performance assessment may represent an annual (or other frequency) assessment alongside other performance assessments, such as operational conditions (recurring congestion, nonrecurring congestion, etc.), or pavement conditions. Using these results, agencies can apply approaches discussed in the HSM and other references noted herein to diagnose site and collision characteristics.

Within operations, agencies often consider a collection of sites for typical improvements based on similarity of characteristics and certain operational needs. These treatments may vary in cost and operational impact. The quantitative safety methods will allow the City to also incorporate safety performance as criteria for selecting the sites and identifying treatments, particularly where the collision experience suggests potential for safety improvement. Examples may include conversion of a stop-controlled intersection to a roundabout, installation of controlled pedestrian crossings, and consideration of all-way stop control. When operational treatments also represent systemic safety treatments, implementation often offers a relatively low-cost solution to lower fatal and serious injury risk on the system.

Decisions in operations and maintenance often include assessments of anticipated changes in performance for different operational and site characteristics. A data-driven approach to safety allows the City to quantitatively assess the change in safety performance (measured in collision frequency and severity) due to operational changes.

Past evaluations for safety consisted of before-after studies, in which the collision performance before implementation is compared to the collision performance after implementation. These more advanced safety analysis methods offer value in that they improve the reliability of results compared to the traditional approach. Some of these methods (e.g., the Empirical Bayes method with comparison sites) also allow the City to control for system wide changes that may be difficult to detect otherwise.

7 Benefits Statement

The City of Waterloo has a long-standing road safety program it believes can become more effective through expanded use of data-driven, evidence-based analysis and decision-making methods. In further embracing this philosophy, the City can also achieve greater alignment with the Region of Waterloo and its well-established road safety program founded on these principles. While the City and Region may employ different analytical tools in performing the work, their collective response to road safety challenges remain consistent in theory and approach.

By promoting and investing in a data-driven, evidence-based approach to road safety, the City will be better positioned to:

- Inform its decision-making process and thereby improve the effectiveness of countermeasures to reduce the number and/or severity of collisions;
- Improve the confidence that safety funds are being applied most effectively;
- Reduce time and improve the justification of safety improvement programs and projects;
- Provide meaningful quantitative safety measures to inform project decisions and thus improve understanding of trade-offs involving other values such as environmental concerns, right-of-way, and stakeholder issues;
- More directly integrate safety into the overall program and project development process; and
- Demonstrate and prove over time, the direct and meaningful return for investments in safety to their sponsors and stakeholders.

In effect, the full implementation will help the City accomplish what its customers and stakeholders expect, which is providing the highest level of safety performance for the financial and other resources provided to the City.

8 References

1 American Association of State Highway and Transportation Officials (AASHTO). 2010. *Highway Safety Manual (First Edition).* Washington, DC.

2 Transportation Association of Canada (TAC). November 2009. *Road Safety Engineering Management Guide: A Book in the Canadian Road Safety Engineering Handbook (CRaSH).* Ottawa, ON.

3 Transportation Association of Canada (TAC). June 2011. *Guidelines for the Network Screening of Collision-Prone Locations: A Book in the Canadian Road Safety Engineering Handbook (CRaSH).* Ottawa, ON.

4 Transportation Association of Canada (TAC). January 2004. *Canadian Guide to In-Service Road Safety Reviews: A Book in the Canadian Road Safety Engineering Handbook (CRaSH).* Ottawa, ON.

5 Federal Highway Administration. October 2016. *Reliability of Safety Management Methods: Network Screening*. Washington, DC.

6 Federal Highway Administration. September 2016. *Reliability of Safety Management Methods: Diagnosis*. Washington, DC.

7 Federal Highway Administration. August 2016. *Reliability of Safety Management Methods: Countermeasure Selection*. Washington, DC.

8 Federal Highway Administration. March 2016. *Reliability of Safety Management Methods: Safety Effectiveness Evaluation*. Washington, DC.

9 Federal Highway Administration. September 2016. *Reliability of Safety Management Methods: Systemic Safety Programs*. Washington, DC.

10 Region of Waterloo. “Region of Waterloo Road Safety Program”. Report to Planning and Works Committee, November 14, 2017.

11 https://www.tes.ca/ (last accessed 2020-05-25)

12 City of Waterloo. 2017. “2017 Traffic Operations Study – Collision Report Analysis”.

13 City of Waterloo. 2017. “2017 Traffic Operations Study – Collision Report Analysis”.

14 TAC. 2011. *Network Screening of Collision-Prone Locations*.

Appendix A

Road Safety Management Process

A.1 Overview

A data-driven **road safety management** (RSM) process provides valuable information for system planning, project planning, design and construction, and operations and maintenance of its road network. Safety evaluation develops the evidence-based information used in the RSM process, which can be integrated into the overall project development process as shown in **Figure A.1**[1].

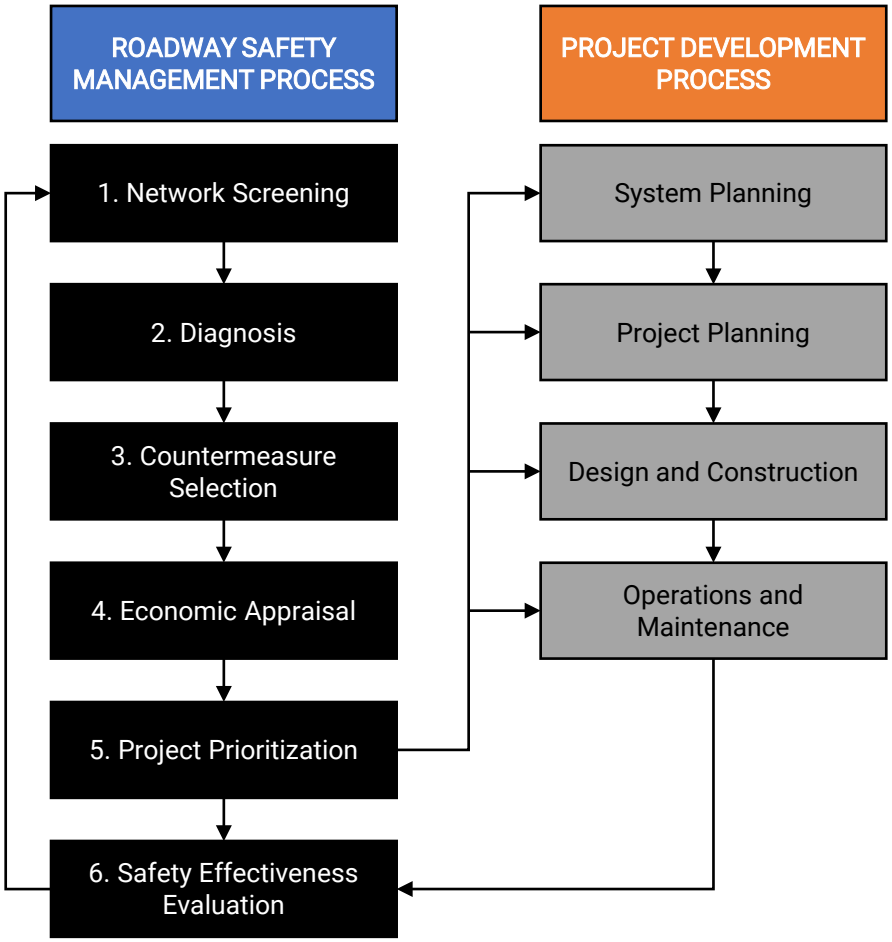


Figure A.1 – Integrating the Road Safety Management Process and Project Development Process
(Source: *Reliability of Safety Management Methods: Countermeasure Selection*, Figure 2)

[1] Transportation Association of Canada (TAC). *Network Screening of Collision-Prone Locations*. 2011.

A.2 Step 1: Network Screening

Network screening is a process for reviewing the safety performance of a road network to identify and rank sites likely to realize a reduction in collision frequency with the implementation of a countermeasure. The process objectively considers collision history, roadway factors, and traffic characteristics to prioritize locations with potential for safety improvement for further detailed analysis in subsequent phases of the RSM process. Accurately identifying locations with the highest potential for cost-effective safety improvement is vital to achieving the greatest benefits and most efficient expenditure of available funds.

According to the TAC *Guidelines for Network Screening of Collision-Prone Location*[2], network screening for the collision-based approach typically involves the following four steps:

- **Step 1: Define Purpose of Screening** – Identify the reason(s) for performing the network screening analysis (e.g., signalized intersection improvement program, locations with high potential for safety improvement, run-off-road collision reduction). This decision will influence data needs and selection of the analytical method used in screening.
- **Step 2: Identify Part(s) of Network and Target Collision Type(s) for Screening** – Specify the type(s) of location or facility to be screened (e.g., segments, intersections, interchanges, urban freeways) and collisions of interest (e.g., run-off-road, angle at signalized intersections).
- **Step 3: Select Screening Method** – Select the preferred method based on the screening purpose, part(s) of the network being assessed, and target collision type(s), considering the availability of safety, traffic and roadway inventory data, SPFs, and software tools.
- **Step 4: Perform Screening and Review Results** – Apply the selected screening method to the identified part(s) of the network and target collision type(s). Review the screening results prior to the in-depth diagnostic component for reasonableness and consistency.

For the systemic approach, an analysis for the identification of focus or emphasis areas would be completed prior to commencing the screening process. Network screening based on the identified and prioritized focus areas will identify those locations with the highest potential for improvement in these specific areas and support development of targeted action plans that include prioritized projects. Examples of focus or emphasis areas identified through systemic analysis include roadway departure collisions on two-lane rural roads, driving under the influence (DUI) collisions, novice driver collisions, and angle collisions at signalized intersections.

The recommended methodology for network screening is based on the Empirical Bayes method for estimating the expected collision frequency of a location. The expected collision frequency is the long-term average number of collisions, often reported as the expected value per year. Advantages and disadvantages of the Empirical Bayes method include:

[2] TAC. *Network Screening of Collision-Prone Locations*. 2011.

Advantages:

The Empirical Bayes method is the most robust, statistically, in estimating expected collisions. The methodology eliminates the potential regression-to-the-mean bias when estimating the expected "long-term" collision counts for locations, enabling the estimation of expected incident occurrences into the future. This avoids flagging locations based solely on short-term, randomly high collision counts. The Empirical Bayes method also properly considers the impact of traffic volume and other factors on expected collision frequencies and provides the option to consider collision severity by weighting severity specific estimates.

Disadvantages:

The Empirical Bayes method is relatively complex, labour intensive and "data hungry". Determination of the estimated mean collision count for locations with similar traits and characteristics requires that Safety Performance Functions (SPFs) be developed. While some jurisdictions have developed SPFs, they are not readily available for all road authorities. Finally, the Empirical Bayes method does not allow comparison of safety levels of different types of locations (e.g., off-ramps vs. intersections) on an equitable basis.

The Empirical Bayes method requires SPFs developed or calibrated from historical data to predict the average collision frequency for similar locations with the same traffic volume. By definition, similar locations share characteristics such as intersection layout or type, traffic control device, number of travel lanes, etc. Examples of typical SPFs include:

$$\textit{Collisions per year} = \alpha\ (\textit{segment length})\ (AADT)^{\beta}\ \text{[Road Segments]}$$

$$\textit{Collisions per year} = \alpha\ (\textit{major road entering AADT})^{\beta_1}\ (\textit{minor road entering AADT})^{\beta_2}\ \text{[Intersections]}$$

where:

- AADTs (Average Annual Daily Traffic) are traffic volumes (vehicles per day)
- α, β, β_1 and β_2 are parameters estimated during SPF development or calibration

Using an SPF, the predicted number of collisions can be estimated for a given AADT. The predicted value represents the average number of collisions for all similar locations, used to develop the SPF, that have the same AADT. The expected collision frequency (or EB estimate) for a specific location is then estimated by combining the predicted number of collisions (i.e., based on the SPF) with the observed collision count (i.e., recorded number of collisions) for this site. The weighted EB estimate is calculated as:

$$EB = w \times N_p + (1 - w) \times O$$

where:

- w is the relative weight given to the predicted and observed collision (w is between 0 and 1)
- N_p is the SPF predicted number of collisions
- O is the observed number of collisions

Figure A.2 illustrates how the observed and predicted collision frequencies for a location are combined with the weighted EB estimate. The figure shows the observed number of collisions per year for a location (O) and the SPF prediction of collisions (N_p) based on the AADT for the site. Note the observed collision frequency is higher than the predicted in this example, a difference that may be due to

location-specific characteristics but could also be the result of a randomly high number of collisions in those years. The Empirical Bayes method combines the observed and predicted collision frequencies into a new estimate (EB), which falls between the two, accounting for regression-to-the-mean.

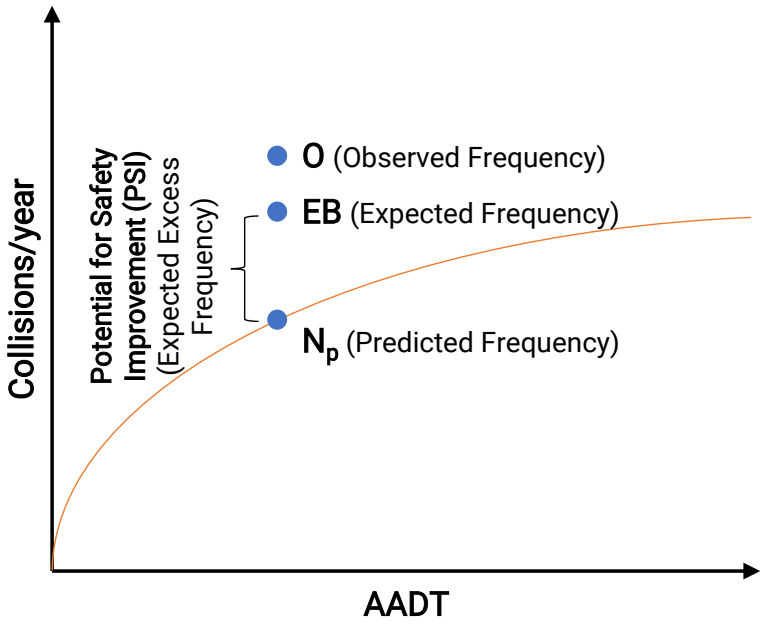


Figure A.2 – Illustrating the Empirical Bayes Method
(Source: *Guidelines for Network Screening Collision-Prone Locations*, Exhibit 3-1)

The next step involves comparing the predicted (N_p) and expected (EB) collision frequencies at a given location. The difference between these values represents the potential for safety improvement (PSI) for a given year. A positive PSI value signifies that the location is performing worse than estimated, which indicates an opportunity for safety enhancement. The opposite is true when a negative PSI value is found, demonstrating that safety at the location is better than anticipated.

The locations should be ranked from the highest to the lowest PSI value, meaning the highest will have the greater potential for safety improvements.

A.3 Step 2: Diagnosis

Diagnosis involves the investigation of sites or high-level safety issues identified through network screening are investigated further to better understand the collision patterns and ascertain the underlying factors contributing to collisions at specific sites. Diagnosis can also help to detect potential safety issues that have not yet manifested in collisions.

The process of diagnosis involves a review of site-specific collision history, traffic operations, and general site conditions. This includes both desktop data analysis and a field visit to observe road user behaviour and site conditions under multiple conditions (e.g., day and night, peak and off-peak travel times, dry and wet). It is also useful to engage a multidisciplinary team to perform the diagnosis and subsequent countermeasure selection.

The HSM recommends the following three-step process for conducting site diagnosis:

- **Step 1: Review Safety Data** – Conduct a detailed review of data from police reports to identify collision patterns and contributing factors. This typically involves reviewing a summary of collision types, collision severity, sequence of events, and contributing circumstances. Different tools such collision diagrams, tabular summaries, bar charts, and pie charts are useful for displaying descriptive statistics. Statistical methods can also be used to identify underlying safety issues based on time trends and collision proportions.
- **Step 2: Assess Supporting Documentation** – Review documented information about the site along with interviews of local stakeholders (e.g., transportation professionals, community groups, local board members) to obtain additional perspectives. Supporting documentation may include traffic volumes, condition diagrams, construction plans and design criteria, photos and maintenance logs, weather patterns, and recent traffic studies.
- **Step 3: Assess Field Conditions** – Conduct a field investigation to examine the road user's experience. An effective field assessment involves travelling the site at different times of day using different modes of transportation. The field review should include observations of traffic operations such as turning movements, conflicts, and operating speeds, as well as accommodation for pedestrians, cyclists, and special road users such as senior pedestrians. Observations of highway and roadside design should also be completed to determine whether the design and location of roadway and roadside features are consistent with road user expectations. The roadside review can also help to determine if roadside recovery zones are clear and traversable.

More reliable diagnosis methods than traditional engineering reviews should be applied such as structured assessments of collision trends over time and use of tests of proportions and the Haddon Matrix[3] to identify contributing factors and develop targeted countermeasures.

A.4 Step 3: Countermeasure Selection

The first task in countermeasure selection is to develop measures to target the underlying safety issues. Tools such as the Haddon Matrix and resources like the HCM can be used to identify potential treatments to address or mitigate the underlying contributing factors.

After identifying potential countermeasures, the safety impact of the treatments needs to be estimated individually and in combination. Positive and negative safety impacts, including contraindications[4] under the specific site conditions (e.g., noise from vehicles traversing speed humps near residences), should be considered. Note countermeasures may produce different results when implemented at different sites with different geometric and operational characteristics. The following three methods are used for comparing countermeasures (listed in order of increasing reliability):

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[3] The Haddon Matrix is a tool originally developed for injury prevention but is directly applicable to highway safety in both diagnosis and countermeasure selection.

[4] Contraindications are negative outcomes measured or observed for specific site conditions after implementation of a given measure.

- **Professional Judgment** – Most experienced practitioners can identify appropriate countermeasures to address or mitigate a given issue. That said, selecting measures based solely on judgment is the least reliable method as it is limited by individual experience and susceptible to personal bias. Using an experienced, multidisciplinary team to diagnose issues and select countermeasures can help to overcome these limitations.
- **Data-Driven Behavior-Based** – More reliable than professional judgment only, the data-driven behaviour-based method draws on research studies and results from previous applications. While the results cannot be used directly to estimate the expected change in collisions, the performance measures, which may include speed, conflicts, lane keeping, and compliance with traffic control devices, help to determine the anticipated effect on road user behavior.
- **Data-Driven Collision-Based** – This method is the most reliable for assessing countermeasures, drawing on research studies and results from previous applications to provide a direct estimate of safety performance. In this method, CMFs are used to quantify and compare the safety effects of potential countermeasures for the specific site conditions. Two popular sources of CMFs are the HSM and the web-based CMF Clearinghouse[5]. In selecting and applying CMFs for this purpose, consider the following four factors to improve reliability of results:
    - Expected Versus Observed Collisions – Where possible, use the EB method to develop more reliable estimates of future collisions without treatment to overcome issues related to variability in collisions and changes in traffic volume over time;
    - Standard Errors – Incorporate the standard error of the CMF to understand the potential range of safety effects rather than using the point estimate alone;
    - Applicability – Use more applicable CMFs to estimate the safety benefit of a potential countermeasure rather than generic ones; and
    - Reliability – Use a higher quality CMF to estimate the safety benefit of a potential countermeasure rather than a lower quality one.

Generally, using more reliable, data-driven countermeasure selection methods will lead to the identification of targeted, effective, and defensible measures to mitigate specific safety issues. The FHWA maintains a list of proven safety countermeasures on its website to assist in selection[6].

A.5 Step 4: Economic Appraisal

Once detailed analysis for the selected problem locations has been conducted and safety improvements identified, the proposed countermeasures or improvements should be quantified as to their cost and (societal) benefits, and integrated with other infrastructure improvements to be funded through capital and operating expenditures. Through this selection process, more than one countermeasure with the potential to remedy the issue is often identified.

Economic appraisals are performed to compare the benefits of potential collision countermeasures to the project costs. The appraisal will evaluate all options for all locations in optimizing an improvement

5 http://www.cmfclearinghouse.org/ (last accessed 2020-05-25)
6 https://safety.fhwa.dot.gov/provencountermeasures/ (last accessed 2020-05-25)

program for a given budget. In an appraisal, costs are typically addressed in monetary terms, although non-monetary factors such as public perception, environmental impacts, and road user needs, may also be considered in decision-making.

Figure A.3 illustrates the economic appraisal process. The process begins with quantifying the safety benefit of the proposed project, expressed as the estimated change in collision frequency or severity. The change is then compared to the countermeasure implementation cost directly (cost-effectiveness analysis) or after converting to a monetary value (benefit-cost analysis). Other project benefits, such as travel time savings and reduced fuel consumption, are not addressed through this process. Only changes related to collision frequency are considered.

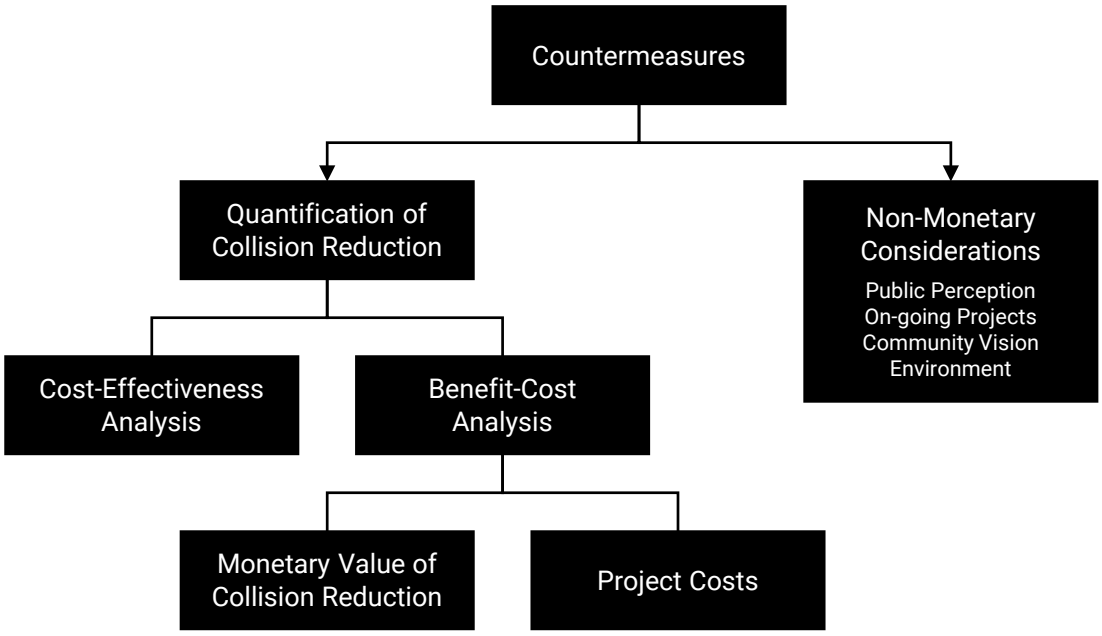

Figure A.3: Economic Appraisal Process (Source: HCM Figure 7-2)

The predictive method presented in Part C of the HSM provides a reliable procedure for quantifying the safety benefit due to a countermeasure. After applying the method to determine expected average collision frequencies for existing conditions and proposed alternatives, the change (difference) in average fatal and injury collision frequency is converted to an annual monetary value using societal collision cost estimates. The monetary value of the expected change in property damage only (PDO) collisions (change in total collisions minus the change in fatal and injury crashes) is calculated in a similar manner. Procedures are also available to estimate the change in expected average collision frequency when the HSM methods cannot be applied, recognizing these alternative approaches are not expected to produce results that are as accurate.

The annual monetary value of the expected change in average collision frequency may not be consistent or uniform over time, necessitating conversion to present value for analysis. The discounting process will depend on whether the annual benefits are uniform or non-uniform over the project service life. Non-uniform annual monetary values can occur if, for example, the countermeasures yield larger changes in expected average collision frequency in the first years after implementation.

Estimating countermeasure implementation costs follows the same procedure as other construction and program implementation projects. Costs are unique to each site and proposed measure and can include right-of-way acquisition, construction materials, grading and earthwork, utility relocation, environmental mitigation, maintenance, and other items, such as planning and engineering design work conducted prior to construction. Construction and/or implementation costs should be expressed in present values for use in economic evaluation, if not already stated in that context. Any annual or future costs like maintenance will need to be converted.

The economic evaluation of countermeasure(s) has two main objectives being to:

- Determine if a project is economically justified (i.e., the benefits are greater than the costs); and
- Determine which project or alternative is most cost-effective.

Benefit-cost analysis (BCA) is typically carried out to satisfy the first objective. The two most common forms of BCA are:

- **Net Present Value (NPV) Method**, which expresses the difference between the discounted costs and benefits of an individual improvement project in a single amount. This method can be used to:
  - Determine which countermeasure or set of countermeasures provides the most cost-efficient means to reduce collisions. Countermeasures are ordered from highest to lowest NPV; and
  - Evaluate if a project is economically justified. An NPV greater than zero indicates the project offers sufficient benefits to justify implementation.
- **Benefit-Cost Ratio (BCR) Method**, which compares the present value benefits of a project to its present value costs. A BCR greater than 1.0 indicates the project is considered economically justified. Countermeasures can be ranked from highest to lowest based on BCR to determine the most valuable measure(s) for a specific site but require an incremental BCA approach to use this tool to compare and prioritize multiple projects or alternatives.

Cost-effectiveness analysis (CEA) is an alternative to BCA used to gain a quantifiable understanding of the "value" of implementing individual or multiple countermeasures at a site without having to convert the estimated average collision frequency reduction to a monetary amount. In this method, the cost-effectiveness of a countermeasure implementation project is expressed as the annual cost per collision reduced. Both the project cost and the estimated average collision frequency reduced must apply to the same period, either on an annual basis or over the entire life of the project.

A.6 Step 5: Project Prioritization

The ultimate decision of which countermeasure implementation projects are constructed involves numerous considerations beyond those presented in Section A.5. This involves an assessment of the overall influence of the projects, as well as the current political, social, and physical environment affecting their implementation. In many cases, the candidate countermeasures will need to be prioritized since cumulative projects costs will often exceed available budgets for safety improvements.

Prior to conducting prioritization, one or more candidate countermeasures will have been identified for possible implementation at each of several sites, and an economic appraisal conducted for each countermeasure to confirm economic justification exists. In this context, the term "prioritization" refers to

a review of possible projects or alternatives for construction and developing an ordered list of recommended initiatives based on the results of ranking and optimization processes.

The HSM identifies three prioritization methods being:

- **Ranking by Economic Effectiveness Measures** – The simplest method of establishing priorities ranks projects or alternatives by various cost and/or benefit factors from high to low. But too simple for situations with multiple competing priorities, budget constraints, or other project impacts.
- **Incremental Benefit-Cost Analysis Ranking** – This approach compares projects in a pairwise manner to derive a ranked list. The differences between the benefits and costs of the two projects are used to compute the BCR for the incremental investment, which determines the ranking; and
- **Optimization (Linear Programming, Integer Programming, Dynamic Programming and Multi-Objective Resource Allocation)** – These methods identify a project set that will maximize benefits within a fixed budget or other constraints, in some cases multiple objective functions. Each uses a mathematical technique for identifying the optimal combination of projects or alternatives based on user-specified constraints.

Ranking by economic effectiveness measures or by the incremental benefit-cost analysis method provides a prioritized list of projects based on a chosen criterion. Optimization methods, such as linear, integer, and dynamic programming, provide project prioritization consistent with incremental benefit-cost analysis but consider the impact of budget constraints in creating an optimized project set. Multi-objective resource allocation can consider the effect of non-monetary elements, including decision factors other than those centered on collision reduction, and can optimize based on several factors.

Table A.1 summarizes the different prioritization methods. Computer software programs are needed to effectively use many of these methods due to their computational complexity.

While the prioritization results provide important input into the decision-making process, it is important to remember the findings are influenced by a variety of factors including:

- How benefits and costs are assigned and calculated;
- The extent to which the evaluation of costs and benefits are quantified;
- The service lives of the projects being considered;
- The discount rate (i.e., the minimum rate of return); and
- The confidence intervals associated with the predicted change in collisions.

It is conceivable these assumptions will prove imprecise over time resulting in a less than optimal prioritization.

There are also non-monetary factors to be considered, as noted in Section A.5. These factors may influence the final allocation of funds through influence on the judgments of key decision makers or through a formal multi-objective resource allocation. As with many engineering analyses, if the prioritization process does not reveal a clear decision, it may be useful to conduct sensitivity analyses to determine incremental benefits of different choices.

Table A.1: Summary of Project Prioritization Methods
(Source: HSM, Table 8-1)

Method	Input Needs	Outcomes	Considerations
Ranking by Safety-Related Measures	Various; inputs are readily available or derived using the methods noted in Section A.6.	A ranked list or lists or projects based on various cost or benefit factors, or both.	The prioritization can be improved by using several ranking criteria. Not effective for prioritizing many project alternatives or projects across many sites. Does not account for competing priorities. The list is not necessarily optimized for a given budget.
Incremental Benefit-Cost Analysis	Present value of monetary benefits and costs for economically justified projects. Spreadsheet and/or a software program.	A ranked list of projects based on the benefits they provide and their cost.	Multiple benefit-cost ratio calculations. Spreadsheet or software is useful to automate and track the calculations. The list is not necessarily optimized for a given budget.
Linear Programming (LP)	Present value or monetary benefits and costs for economically justified projects. Spreadsheet or a software program, or both.	An optimized list of projects that provide: 1. Maximum benefits for a given budget, or 2. Minimum cost for a predetermined benefit.	Generally, most applicable to roadway projects without defined limits. Microsoft Excel can be used to solve LP problems for a limited set or values. Other computer software packages are available to solve LP problems that have many variables. There are no generally available LP packages specifically customized for highway safety applications.
Integer Programming (IP)	Present value of monetary benefits and costs for economically justified projects. Spreadsheet or software program, or both.	An optimized list of projects that provide: 1. Maximum benefits for a given budget, or 2. Minimum cost for a predetermined benefit.	Generally, most applicable to projects with fixed bounds. Microsoft Excel can be used to solve IP problems for a limited set of values. Other computer software packages are available to efficiently solve IP problems. SafetyAnalyst and RSRAP provide IP packages developed specifically for highway safety applications.
Dynamic Programming (DP)	Present value or monetary benefits and costs for economically justified projects. Software program to solve the DP problem.	An optimized list of projects that provide: 1. Maximum benefits for a given budget, or 2. Minimum cost for a predetermined benefit.	Computer software is needed to efficiently solve DP problems.
Multi-Objective Resource Allocation	Present value of monetary benefits and costs tor economically justified projects. Software program to solve the multi-objective problem.	A set of projects that optimizes multiple project objectives, including safety and other decision criteria, simultaneously in accordance with user-specified weights for each project objectives.	Computer software is needed to efficiently solve multi-objective problems. User must specify weights for each project objective, including collision reduction measures and other decision criteria.

A.7 Step 6: Safety Effectiveness Evaluation

The objective of safety effectiveness evaluation is to determine how a treatment (or group of treatments) has affected the safety performance (collision frequency and severity) at the subject location(s). Agencies will use the results of these evaluations in future decisions about funding allocations and policy changes. In some cases, the evaluation leads to a CMF.

The HSM identifies three alternative study designs for evaluating safety effectiveness:

- Experimental Before-After Studies
- Observational Cross-Sectional Studies
- Observational Before-After Studies

In experimental studies, researchers randomly select sites for treatment and control, and then administer the treatment to the subject group. These types of studies tend to be less common for road safety projects because agencies do not randomly identify sites.

In observational studies, researchers are limited to sites already selected for treatment based on other reasons, consistent with the approach for highway safety investigations. Within the observational category, there are two broad classifications:

- **Cross-Sectional Studies**, which include investigations comparing the safety of one group of entities having some common feature to the safety of a different group of entities not having that feature to assess the safety effect of that feature (e.g., STOP versus YIELD signs).

  In these studies, CMFs are developed by comparing the safety of a group of sites with a feature to the safety of a group of sites without that feature. The CMF is then estimated as the ratio of the average collision frequency of sites with and without the feature. For this method to work, the two groups of sites should be similar in their characteristics except for the feature. In practice, this is difficult to achieve, and multiple variable regression SPFs are typically used. The variable coefficients from these equations are used to estimate the CMF associated with a treatment.

  The primary criticism of CMFs estimated from cross-sectional studies is the potential for confounding. Confounding occurs when the method does not account for extraneous variables correlated with both the dependent variable (collision frequency) and the independent variables in the model.

- **Before-After Studies**, which include all techniques that study the safety effect of some change that has been implemented on a group of entities (e.g., road sections, intersections, drivers, vehicles, neighbourhoods).

  In these studies, CMFs are developed by comparing the frequency and severity of collisions before and after implementation of the treatment. A key to before-after studies is accounting for site selection bias, which can lead to regression-to-the-mean issues. Without properly accounting for these issues, a safety effectiveness evaluation may incorrectly over or underestimate the treatment effect. Before-after evaluations must also account for changes in traffic volumes and other temporal trends that can impact collision experience.

The following describes the four common methods of conducting before-after studies, highlighting the ability (or inability) of each method to address regression-to-the-mean issues and changes in traffic volume, driver behavior, collision reporting, and other temporal trends:

- **Simple Before-After Study** – The safety effect of a treatment is assessed by directly comparing the collision frequency before and after implementation. This study design does not account for possible bias or temporal effects or trends;
- **Before-After Study with Traffic Volume Correction** – A variation of the simple before-after study that accounts for changes in traffic volume over time (e.g., comparing rates rather than counts). This study design assumes the volume correction is linear, which is not usually the case. It also does not account for possible bias or temporal effects or trends other than traffic volume.
- **Before-After Study with Comparison Group** – Information from an untreated group of sites is incorporated to account for temporal effects and changes in traffic volume. In this method, a comparison group is used to calculate a comparison ratio, defined as the ratio of collision frequency in the after period to collision frequency in the before period. The collision frequencies applied can be either observed or predicted from SPFs developed from the comparison group (preferred). The ratio is used to contrast collision experience with and without the treatment in the after period, thereby accounting for changes in traffic volume and the nonlinear relationship between collision frequency and traffic volume. That said, the method does not account for regression-to-the-mean or other temporal trends. But it may be a viable approach if sites are not selected for treatment based on collision history (e.g., blanket installation of a treatment), which reduces the concern for possible bias.
- **Empirical-Bayes Before-After Study** – The EB method addresses bias due to regression-to-the-mean, accounts for changes in traffic volume, and accounts for temporal effects. The intent of the EB method is to estimate the expected number of collisions that would have occurred had there been no treatment and compare that with the number of observed collisions after treatment.

14 EMERGING TECHNOLOGIES AND TRENDS IN TRANSPORTATION

Technical Memorandum

Date: November 3, 2020

To: Christopher Hodgson, City of Waterloo

From: Gene Chartier, Paradigm Transportation Solutions Limited

c.c.: Kate Whitfield, Alta Planning + Design
Susan Hall, Lura Consulting

Re: **Emerging Technologies and Trends in Transportation**

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1 Introduction

The transportation sector is witnessing significant changes in the technologies used and attitudes towards moving people and goods. Municipalities need to develop appropriate responses to these emerging trends, adapting and evolving current transportation and land use planning policies and practices to position their communities to be ready for and (hopefully) benefit from this transformational and shift in mobility services.

Through the **City of Waterloo Transportation Master Plan (TMP) Update**, the City can help establish the principles and key components of its response to emerging technologies and trends in transportation and provide the foundation for further research and action. This memorandum identifies the important considerations for the TMP Update and is organized as follows:

- Chapter 2 lists emerging technologies and trends in transportation and highlights the ongoing and impending changes most relevant to the City of Waterloo;
- Chapter 3 documents existing or completed City initiatives in this field;
- Chapter 4 summarizes current initiatives underway in other Ontario municipalities and jurisdictions around the world potentially applicable to the City of Waterloo;
- Chapter 5 outlines the recommended actions pertaining to emerging technologies and trends;
- Chapter 6 identifies potential impacts on capital, operating, and maintenance practices;
- Chapter 7 provides a benefits statement; and
- Chapter 8 lists the documents referenced in the memorandum.

Some of the emerging trends and technologies discussed in this document are also referenced in the **Complete Streets Review** memo prepared for the TMP Update.

2 Best Practices

Increased environmental awareness, advancements in technology, rising life expectancies, people working longer hours, and Millennials (the generation marked by elevated usage of and familiarity with the Internet, mobile devices, and social media) entering the workforce are contributing to fundamental changes impacting mobility. These changes are contributing to five converging mobility innovations[1]:

- **Shared Mobility**: Shared mobility enables users to gain short-term access to transportation modes on an "as-needed" basis. The ecosystem of shared transportation services continues to grow and includes an array of services, such as car sharing, microtransit, shared micromobility (e.g., bike sharing and e-scooter sharing), transportation network companies and public transportation;
- **Digital information and Fare Payment Integration**: These services can help bridge information gaps, make multimodal travel and public transit more convenient, and enhance decision-making with dynamic and real-time information throughout an entire journey;
- **The Commodification of Transportation**: Consumers are assigning economic values to modes and engaging in multimodal decision-making processes based on a variety of factors such as cost, journey time, wait time, number of connections, convenience, and other attributes. Rather than making decisions between modes, mobility consumers can make decisions among modes, in essence "modal chaining" to optimize the route, travel time, and cost;
- **Automation**: Vehicle automation also has the potential to create new and exciting opportunities for both the public and private sectors, such as cost savings; automated pick-up, drop-off, and charging; and more economical and convenient demand-responsive services; and
- **Electrification**: Electric drive vehicles that use one or more electric or traction motors for propulsion can reduce GHGs and other emissions, mitigating many of the transportation-related impacts associated with increased urbanization in cities.

The following sections provide further information on the emerging technologies and trends in transportation with the greatest potential interest and/or applicability to the City of Waterloo[2].

2.1 Shared Mobility

Shared mobility is defined as "the shared use of a motor vehicle, bicycle, or other low-speed transportation mode" that "enables users to obtain short-term access to transportation on an as-needed basis, rather than requiring ownership"[3]. The first carsharing and bikesharing programs in North America launched in 1994, with other shared mobility services expanding rapidly since that time.

Interest in shared mobility has grown tremendously in recent years with technological, socio-demographic, and behavioural changes and as society seeks more sustainable alternatives to the private automobile[4]. This evolution in mobility can be traced to the emergence of the sharing economy. Defined as a peer-to-peer activity of acquiring, providing, or sharing access to goods and services, the modern sharing economy is typically facilitated by a community-based online digital platform[5]. The rapid advancement of technology, particularly in smartphones and mobile applications, has contributed to this evolution, with real-time information about where, when, and how to access or connect between different travel modes now readily available.

Through the sharing economy rose mobility on demand (MOD) and mobility as a service (MaaS):

- MOD is based on the principle that different transportation modes have different economic values due to cost, trip time, wait time, number of connections/transfers, convenience, etc. MOD services allow users to access mobility, goods, and delivery services on demand creating an accessible multi-modal network. Four main MOD business models have evolved, being:
    - Business to Consumer (B2C)
    - Business to Government (B2G)
    - Business to Business (B2B)
    - Peer to Peer (P2P)

    Through supportive public policies, commonly involving rights-of-way, grants and direct subsidies, municipalities can influence the success and growth of MOD.
- MaaS is a platform that offers integrated transportation through subscription services. The platform is typically a mobile based app that contains all available transportation mode service information and payment in one convenient location. The idea is that the freedom and convenience to choose the most appropriate form and combination of travel for every trip alleviates the need to privately own a vehicle.

Figure 1 compares the concepts, illustrating the relationship between MOD and MaaS. In general terms, MOD is often referred to as how people or goods move from point A to point B, and which mode(s) are selected based on time, cost, and convenience[6]. It emphasizes the commodification of passenger mobility, goods delivery, and transportation systems management. The term MaaS is typically used when discussing the software applications people use to make travel decisions and the data used to study that travel[7]. It primarily emphasizes passenger mobility allowing travelers to seamlessly plan, book, and pay for a multimodal trip on a pay-as-you-go and/or subscription basis. The concepts are similar because they both involve integration of transportation modes through fares, a digital interface, and physical mobility options[8],[9].

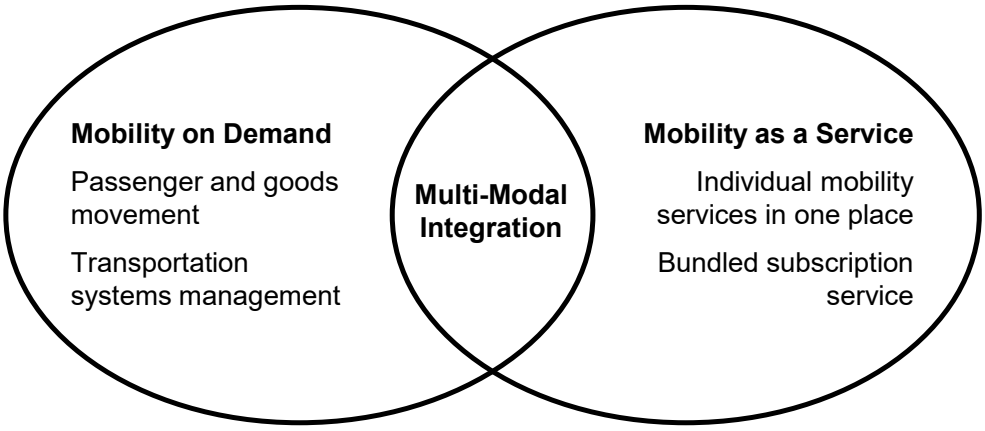


Figure 1: Relating Mobility on Demand and Mobility as a Service (Source: ITE Journal, Susan Shaheen and Adam Cohen, 2020)

New technologies and ideas in shared mobility continue to grow. In the broad sense, most forms can be categorized as either a transportation network company (TNC) or mobility service provider (MSP). Both rely on a smartphone application to connect individual users with a travel mode. **Figure 2** illustrates current examples of shared mobility options.

Figure 2: Examples of Shared Mobility

The most prominent forms of shared mobility currently, and those with the highest potential applicability in Waterloo, include:

- **Car Sharing** – A service that provides members with access to an automobile for intervals of (typically) less than a day, alleviating the need for users to privately own a vehicle. Two primary models exist:
    - *Fleet operations*, where a company supplies and maintains a fleet of vehicles in pre-positioned locations (i.e. pick-up and drop-off at same location) or "floating" within a defined boundary (i.e. pick-up and drop-off at different locations). Current examples include Enterprise, Zipcar and Communauto; and
    - *Peer-to-peer operations*, where individuals share their personal vehicles directly with other carshare subscribers. Turo is a current example.
- **Bike Sharing** – A service that offers short-term bike rentals, usually for periods of an hour or less. The rental period can range from a single ride, to several days, to an annual membership. Modern bike share systems use one of three types of technology:
    - *Docked systems*, where bicycles are rented from an automated station (locked "docking stations" or "docks") and returned to a station belonging to the same system. This system can be modular and consist of docking plates and kiosks that use solar power and wireless communications. Bike Share Toronto and BIXI Montreal are current examples;
    - *Dockless system*, where self-locking and free-floating bicycles that can be locked anywhere within a designated service area, are either locked to a fixed object or a locked to itself. Although not prevalent in Canada currently, examples in the United States include Lime, Jump and Bird; and
    - *Hybrid system*, where "lock-to" feature smart locks require locking the bike to a fixed object or designated station.

- **Electric Kick-Style Scooter (E-Scooter) Sharing** – A service in which electric motorized scooters (also referred to as e-scooters) are rented for short-term use. E-scooters are typically "dockless", like the bike sharing service. Although not prevalent in Canada currently, examples in the United States include Lime, Jump and Bird.

  In fall 2018 and spring/summer 2019, the City participated in the first Canadian e-scooter pilot program. The pilot area included the David Johnston Research and Technology Park ("R&T Park") and extended slightly into the Idea Quarter district and along the Laurel Trail to the Uptown Promenade. The Provincial Government has since launched a pilot program on January 1, 2020 to permit e-scooters on Ontario roads. For the pilot, the province has set out the broad rules and requirements for e-scooters. Municipalities must then pass by-laws to allow their use and determine where they can operate most safely in each unique environment.

- **Ride Sharing, Ride Hailing and Ride Sourcing** – A service that involves adding passengers to a private trip in which the driver and travellers share a common destination. Traditional forms of ride sharing services include carpooling and vanpooling. Today, TNCs such as Uber and Lyft are examples of ride hailing services although their "pool" functions are akin to ride sharing. A ride sourcing service, like Poparide, that allows individuals to coordinate shared rides through an online app.

  There may be a role for ride sharing, ride hailing and ride sourcing platforms to serve longer distance, intermunicipal trips not accommodated by transit or local taxis.

- **Shuttles** – A service that relies on small buses or vans to provide public mobility within a defined area. A form of "microtransit", two common models exist:

  - *Circulating shuttles*, which carry passengers for short trips along a fixed route to/from specific destinations and designated locations such as transit stops, offices, stopping, and community facilities; and
  - *Demand-responsive shuttles*, which transport passengers, often door to door, in vehicles that alter their routes based on demand rather than following a fixed timetable.

  Like ride sharing, shuttles could play a limited role serving trips not met by transit or other modes.

Shared mobility services can be successful in addressing the transportation challenges of communities like Waterloo, providing a viable solution to the "first and last mile dilemma" and offering mobility options for individuals without automobiles. These services can complement the transit system and offer efficient, cost-effective options to single-occupant vehicle travel, thereby reducing the volume of short distance auto trips.

Municipalities typically use by-laws, policies, and guidelines to influence the availability, viability, and delivery of shared mobility services. The most common matters addressed through municipal direction include the allocation of public rights-of-way space (e.g., parking, curb space), development and zoning regulations, insurance, and for-hire vehicle regulations (e.g., licensing), and taxation and fees.

Before deciding on the type of service(s) to pursue and/or permit, a shared mobility strategy should be developed for the community. The strategy should identify the specific transportation needs to be addressed and articulate a case for the service(s) that best suits requirements. Tools such as surveys,

pilot projects and incentives could be used as part of the strategy to gauge local interest level. The study should engage a cross-section of local stakeholders and potential partners to ensure broad support for the initiative and ultimately facilitate implementation.

The shared mobility strategy should consider the merit of introducing/piloting an “EcoMobility” hub(s) in the City, possibly in the Uptown area or near the university and college campuses. These hubs serve as one-stop service points for multimodal systems and typically feature a range of shared mobility services including bike share, ride share, and car share facilities. **Figure 3** illustrates the concept.

Figure 3: EcoMobility Hub Concept
(Source: Multi Mobility, Sophia von Berg, 2014)

An opportunity may exist to leverage the planned transit plaza at the University of Waterloo Station for a type of EcoMobility hub. The plaza will increase bus access to the interior of campus, allow GRT routes to connect directly to the new ION light rail station, and provide access to new developments on Phillip Street. It could also provide the base for shared mobility services with easy access to the Laurel Trail for cyclists and pedestrians and connections to business and services along University Avenue.

The shared mobility strategy should reflect the following guiding principles[10]:

- Shared mobility impacts everyone, not just users, due to its impacts on the transportation network and the environment;
- Providing clear and consistent definitions can help reduce confusion about the different models;
- Public-private partnerships can enhance shared mobility options;
- The public and key stakeholders should be informed and involved in the planning process;
- Collecting data and reporting findings help build understanding of the impacts of shared mobility and enhance performance;
- Shared mobility should be incorporated into transportation planning;
- Social, interregional, and intergenerational equity needs to be encouraged to the extent possible; and
- Shared mobility developments should be tracked, and sound policies developed for managing rights-of-way and public-private partnerships.

2.2 Automated, Connected and Electric Vehicles

Over the past decade, the automotive industry has experienced considerable change due to innovation and rapidly evolving technology, some of which impacts local governments. Potentially transformative automobile technologies likely to have significant effects on municipal land use and transportation in the coming 10 to 30 years include:

- **Automated Vehicles (AVs)**, which have at least some aspect of a safety-critical control function (e.g., steering, throttle, or braking) occur without direct driver input. There are six levels of vehicle automation, starting from Level 0: No Automation to Level 5: Full Automation (or Autonomous), as defined by the Society of Automated Engineers (SAE) International;
- **Connected Vehicles (CVs)**, which rely on different wireless communication technologies to communicate with the driver, other cars on the road (vehicle-to-vehicle [V2V]), roadway infrastructure (vehicle-to-infrastructure [V2I]), and the "Cloud" [V2C], and
- **Electric Vehicles (EVs)**, which use one or more electric or traction motors for propulsion. An EV may be powered through a collector system by electricity from off-vehicle sources, or may be self-contained with a battery, solar panels, or an electric generator to convert fuel to electricity.

Automated, connected, and electric (ACE) vehicles, as illustrated in **Figure 4**, offer promise to improve transportation system safety and efficiency in communities. From a positive perspective, they have the potential to:

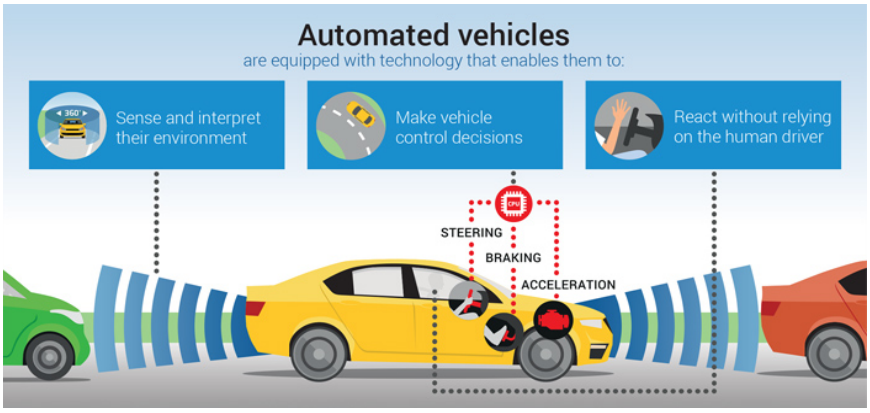
- Reduce collisions, traffic congestion and emissions;
- Improve mobility and equity, particularly for youth, seniors, and individuals with disabilities; and
- Lessen the need for roadway expansion and on-site parking.

At the same time, if not deployed and managed properly, these technologies could lead to more traffic, inequitable access to mobility, and adverse environmental impacts.

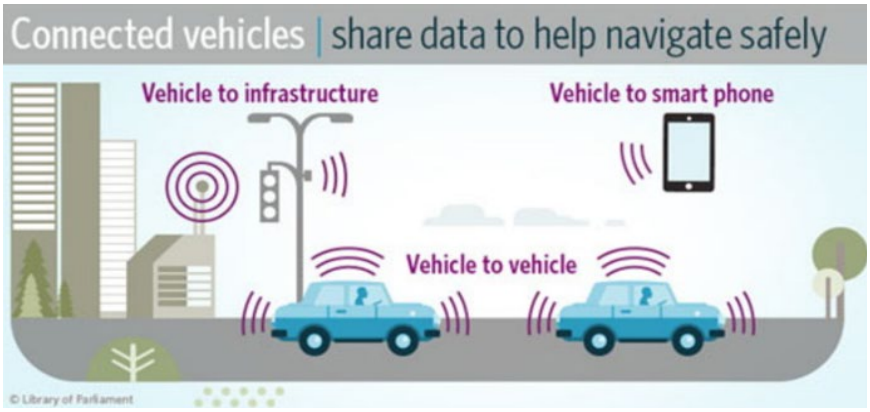
The future of ACE vehicles, especially AVs and CVs (collectively referred to as CAVs), could be highly disruptive, for better or worse. Gaining a better understanding of the likely outcome is complex and difficult to fully grasp at this time given:

- CAVs may have a broad range of economic and social impacts, many of which extend beyond transportation and are unknown or dependent on further information;
- The potential effects of widespread CAV use are both positive and negative;
- Timelines for the arrival of CAVs are uncertain; and
- The impacts of accommodating CAVs on existing transportation infrastructure (e.g., signs, pavement markings, lane drops) are not well understood, especially implications for design and standards.

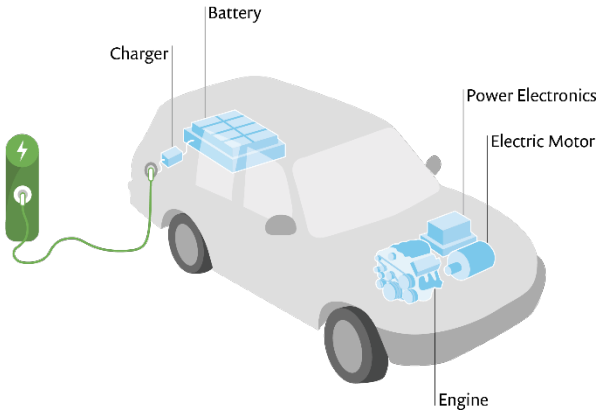
Capitalizing on opportunities and effectively addressing risks will require governments to prepare carefully. The *Automated and Connected Vehicles Policy Framework for Canada*[11] sets out the following six guiding principles for initiatives and policies related to introducing CAVs on public roads:



(Source: https://www.autonomousvehicleinternational.com/news/business/eu-auto-makers-publish-automated-driving-checklist.html#prettyPhoto/0/)



(Source: https://startupheretoronto.com/partners/mentor-works/connected-vehicles-innovative-technology-driving-market/)



(Source: https://www.kindpng.com/downpng/hhomibb_transparent-electric-car-png-city-car-png-download/)

Figure 4: Automated, Connected and Electric (ACE) Vehicles

1. *Prioritize safety* – While there is pressure to adapt quickly to emerging technologies, safety is a top priority for testing and deploying these vehicles;
2. *Exchange information to ensure CAVs are safe and secure* – Data needs to be shared with governments and law enforcement while protecting privacy;
3. *Align CAV policies and regulations* – A common, coordinated approach within Canada (and outside the county) is essential;
4. *Raise public awareness of the capabilities and limitations of CAVs* – Governments, as well as industry, will play an important role in education and outreach;
5. *Prepare proactively for the deployment of CAVs on public roads* – All levels of government must ready themselves for the potential safety, mobility, and land use planning implications of these technologies; and

Collaborate continually with those involved in the CAV sector – A culture of cooperation and collaboration will be essential to successful implementation.Overall, the framework recommends that municipalities advocate and accommodate testing of CAVs and start adapting infrastructure to support their deployment.

Consistent with these principles, the role and responsibilities for municipalities in the introduction of ACE vehicles can include[12]:

- Enacting and enforcing traffic and parking bylaws;
- Facilitating trials and deployment on municipal roads (In 2016, the province launched a ten-year pilot program allowing the testing of AVs on Ontario roads);
- Adapting and implementing infrastructure, like signs and pavement markings, to support deployment;
- Implementing curb management strategies to organize operation and designate areas for vehicle dwelling;
- Implementing or modifying policies pertaining to the supply and management of on-street, municipal lot, and private, off-street parking;
- Developing strategies to repurpose infrastructure and land no longer required for parking;
- Managing and regulating passenger transportation impacted by deployment (including public transit, taxis, and shared mobility services);
- Creating and managing new logistics, regulations, and revenue structures for traffic and parking control;
- Engaging, educating, and raising awareness with the public; and
- Establishing funding streams for related initiatives.

The installation of EV charging stations in municipal parking lots and on-street is another action being taken by municipalities to support ACE vehicle use. By helping to make electric vehicles more convenient, municipalities hope to encourage greater use of this environmentally friendly alternative to lower their overall carbon footprint. In some communities, municipalities are partnering with private companies (such as Tesla) to implement the stations. At present, Waterloo has several EV charging stations[13] including installations at City Hall and several City-owned parking facilities.

2.3 Smart Cities and Big Data

The rapid rise of urbanization has, in recent years, coincided with a massive growth in connected devices (or things that talk to the internet). With this steady expansion of the Internet of Things (IoT), there is significant opportunity for Canadian municipalities to empower their communities through information and communications technology (ICT) and connectivity. By employing this connectivity, cities can leverage investments in technology to support smarter, healthier, and more equitable and sustainable communities[14].

While there is no consensus definition, a "smart city" is generally one that improves overall quality of life for people at home, work and play using data and connected technology integrated throughout the built environment. Technology is used to provide opportunities for economic development and enhance urban services, resource conservation and cost effectiveness. These solutions are built on a foundation of high-speed broadband and open data with policies for data inclusion and data privacy.

"Big data" is commonly considered a critical component of a smart city. For public agencies, data becomes "big" when the data cannot be conveniently analyzed by traditional statistical methods or common software tools. From a transportation perspective, big data is commonly used for identifying trends with spatial (location-based) precision (e.g., road safety analysis) and improving municipal service delivery (e.g., public transit routing).

Transportation and mobility are typically integral components and a key benefactor of a smart city initiative. Better connected transportation systems offer some of the greatest potential to drastically enhance efficiencies within a city. Intelligent traffic signals that optimize traffic flow, parking management systems that capitalize on additional revenue streams, and public transit apps that allow riders to track bus locations are a few examples of smart city technologies that allow municipalities to better serve citizens.

Transportation in a smart city should not be driven by competition between different travel modes, each of which aims to dominate the market. A successful system will combine and integrate multiple modes to offer passengers the best mobility solution.

2.4 Unmanned Aerial Systems (Drones)

Unmanned Aerial Vehicles (UAVs), also known as drones, are designed to deliver lightweight and small freight over short distances by air[15]. These devices can be remote-controlled by a person or automated.

UAVs have the potential to reduce road congestion (due to fewer delivery trucks on the road) and the space needed for loading trucks (since they do not require designated loading spaces on the ground). They could also impact location decisions (e.g., distribution centre locating in "drone-friendly" location) and infrastructure design (e.g. drone accessible lockers). Additionally, policy and planning changes will be required to ensure safety and security of the public.

3 Past and Current Initiatives in the City of Waterloo

The City of Waterloo has participated in the following initiatives related to the emerging technologies and trends discussed in Section 2 above:

3.1 E-Scooter Pilot Project

In 2018, the City was approached by Neutron Holdings Inc. (Lime) to conduct an e-scooter pilot in Waterloo. Key objectives of the pilot were to:

- Better understand e-scooter transportation patterns and user behaviour within the pilot area;
- Expand multi-modal transportation options along the Laurel Trail and within the Research and Technology Station Area;
- Identify recommendations for longer term e-scooter micro-mobility in Waterloo; and
- Collaborate with local stakeholders and share findings with the Ministry of Transportation.

Longer term objectives include reduced car use; increased transit ridership, and reduced carbon footprint.

Through a collaborative effort, a pilot route was identified as a “living lab” experience. The pilot area included the David Johnston Research and Technology Park (“R&T Park”) and extended slightly into the Idea Quarter district and along the Laurel Trail to the Central Promenade in Waterloo Park.

Specific measures introduced through the pilot project included an enhanced geofence boundary, designated e-scooter parking locations, maximum speed caps, and proactive user engagement. The City was also given access to data collected (subject to applicable laws) to evaluate the initiative.

Despite some early concerns about safety and environmental impact on trails, the City considered the pilot a success. Between October 2 and November 30, 2018, more than 6,000 different riders completed more than 18,000 trips on the 150+ e-scooters deployed, riding for about six minutes per trip and travelling more than 19,000 kilometres. During the second phase from April 1 to August 12, 2019, the scooters were limited to approximately 5.5 km of infrastructure and was extended on May 28, 2019 to include the main campus of the University of Waterloo. Over the duration of the pilot, approximately 43,000 trips were completed.

Lime decided not to renew the pilot project following the end of the second phase. The company cited the Ministry of Transportation’s (MTO) position on electric scooters as the reason for the withdrawal. At the time, Ontario legislation prohibited e-scooter use on public streets.

As part of the Province’s plan to help businesses expand and allow consumers and commuters more choice, MTO announced a five-year e-scooter pilot (that started on January 1, 2020). Municipalities that want to allow e-scooters to operate on their roads must pass by-laws to permit their use, while determining what is best for their community.

The Region of Waterloo and area municipalities have completed a Shared Micromobility Feasibility Study. The report explored a recommendation that the Region permit e-scooters as a pilot program that would build on the City of Waterloo’s experience. The report recommended e-scooters and bike share systems use the same services area boundaries. High areas apply to both forms of micromobility.

3.2 Bike Share Pilot Program

In 2018, the Region of Waterloo and Cities of Waterloo, Kitchener, and Cambridge selected Dropbike to participate in a free one-season pilot, providing bike share to urban centres. Dropbike is a dockless bike sharing system that delineates parking areas (or havens) using geofencing. Riders are incentivized to return their bikes to the havens to minimize obstruction to public spaces. Users pay a $50 deposit and are charged $1 per hour for the time that the bike is unlocked. Memberships are available to reduce the cost of frequent use.

Since Dropbike launched the service on May 13, 2019, users have taken over 4,600 rides in Waterloo Region. At the peak of the cycling season, there were approximately 400 bikes in the service area.

The Dropbike pilot provided lessons learned to improve bikeshare service to the Region of Waterloo. The recommended number of bikes, services area, and regulatory checklist build upon the pilot and its perceived challenges. The Shared Micromoblity Feasibility Study recommended an overall carefully planned and managed “lock-to” (hybrid”) system is most likely to achieve the program goals and objectives over the long-term. A permit-based system is recommended to bring bike share operators to the Region.

3.3 Community CarShare

In 1998, the People’s Car Co-operative Inc. (known informally as the Community CarShare) became the first legally incorporated car sharing co-operative in Ontario. Operating in Kitchener, Waterloo, Hamilton, Elmira, Guelph, St. Catharines and London, Community CarShare provided members with access to vehicles on a self-serve, pay-per-use basis.

To facilitate its development, the City extended Community CarShare a $30,000 line of credit to assist in financing operations. The City also provided the organization parking spaces at various municipal facilities on an informal basis at no charge to use as vehicle locations.

After years of financial difficulties, members of the Community CarShare voted on November 22, 2017 to dissolve the cooperative. This decision was reached after receiving a letter of intent from VRTUCAR, a subsidiary of for-profit car sharing company Communauto Inc., to purchase the entity. With the transfer, the City discontinued its financial support of Community CarShare and the provision of free parking spaces.

3.4 Electric Vehicle Charging Stations

In 2018, the City acquired three dual port curbside electric vehicle charging units (six parking spaces) under the FLO Downtown City Curbside Electric Vehicle Charging Unit NRCAN Program. The units were installed on William Street (adjacent to Waterloo City Hall) and Father David Bauer Drive (at intersection of Erb Street). The City also purchased a dual port charging station that was installed in the Waterloo Town Square North Lot. Previously, in 2014, the City had entered into an agreement with the Region of Waterloo to locate a dual port charging station on City land at Waterloo City Hall.

3.5 Autonomous and Connected Vehicle Research

The Waterloo Centre for Automotive Research (WatCAR) at the University of Waterloo focuses on collaborative research in automotive and transportation systems by facilitating relations between those within the automotive industry and University of Waterloo faculty researchers. The centre is dedicated to the research and practice of ever-changing on-board computer procession and combining this with new technologies. The purpose is to connect vehicles deeper into autonomous driving.

The presence of WatCAR in Waterloo offers the opportunity to raise awareness and knowledge of CAVs locally and could be leveraged to advance deployment in the City.

4 Review of Other Municipal Initiatives

A review of initiatives in other Ontario municipalities and jurisdictions around the world was undertaken to identify activities potentially applicable to the City of Waterloo. Only a few municipalities in the province have published documents pertaining specifically to emerging technologies and trends, with none comparable in size to Waterloo (Cities of Toronto, Ottawa and Mississauga). Several western Canadian cities have examined the topic and developed strategies, as have cities in the United States and Australia.

The following summarizes the research findings:

4.1 City of Toronto

The City of Toronto has many initiatives underway relating to emerging trends and technologies, especially CAVs. The document *Preparing the City of Toronto for Autonomous Vehicles (2018)*[16] provided an overview of the steps taken by the City to date and actions proposed to prepare for the introduction of automated vehicles. The overview includes:

- A brief description of automated vehicles, the regulations that exist in Canada regarding their use, and lists the companies that have been approved for testing AVs;
- A summary of early public opinion on AVs;
- A summary of actions that the Transportation Services Division has taken to prepare for the change (forming an internal working group, partnering with the University of Toronto to produce a discussion paper, forming an interdivisional working group, and implementing a three-year work plan); and
- A summary of the potential implications for City divisions and agencies.

The overview identified several partnerships that the City has made with academic, professional and government organizations to jointly explore issues around vehicle automation and to build capacity.

More recently, the City has completed its *Report for Action: Automated Vehicles Tactical Plan and Readiness 2022 (2019)*[17] outlining the path forward to prepare the City for the introduction of highly automated vehicles. Based on the City's strategic vision for mobility, the plan created a set of seven high-level directions outlining how the city will support and manage the adoption of automated vehicles.

A series of goals were then developed to illustrate what the City would look like by 2050 upon achieving these seven directions.

The document includes a three-year action plan to move the City forward on the overall Tactical Plan. The action plan included:

- Carrying out an Automated Shuttle Trial at Rouge Hill GO Station;
- Developing Transportation Innovation Zones – an internal process and external facing portal to ensure systematic review, public consultation, and decision-making regarding transportation technology trials proposed by third party actors;
- Developing a Testing Response and Incident Preparedness System;
- Continuing public education; and
- Developing a research and development program to investigate issues and applications related to AVs, setting a foundation of knowledge before moving forward with the implementation of new programs and policies.

4.2 The City of Calgary

The *Future of Transportation in Calgary (2017)*[18] outlines emerging trends and technologies deemed to be most impactful to the City of Calgary and how the municipality can best prepare a response, either through policy revisions or further research. The report included a more detailed assessment of the technologies with a higher level of impact on the transportation network that are further along in their development, which included autonomous vehicles (Levels 3 to 5), aerial delivery drones, electric vehicles, e-bikes, connected vehicles, MaaS, Internet of things (IoT), and parking technology. Next steps for the City in responding to each technology were noted.

For the City of Calgary to be resilient and future-ready, continual, and ongoing monitoring and adjustment of plans and strategies will be critical. To this end, the report recommends the City:

- Continue to monitor development in technologies that are expected to significantly change travel and land use patterns in the future;
- Continue to collaborate with other jurisdictions, academic institutions, and industry;
- Undertake pilot projects;
- Update City strategies and bylaws; and
- Participate in the Smart Cities Challenge.

4.3 City of Edmonton

The City of Edmonton developed the *Smart Transportation Action Plan (2018)*[19] to prioritize actions in the mobility sector for the immediate term (two to three years). This plan outlines actions that are both new and in progress to better inform what the City is currently doing, and what could be done, to prepare for emerging transportation technologies. Eventually, these actions will feed into and integrate with the City's broader city building strategies and plans.

The plan was developed through a multi-stage process informed by a state of practice review; input from City staff, industry, and academia; research with citizens; and validated through expert advice from a Subject Matter Expert Think Tank. It focuses on automated, connected, shared and electric

mobility technologies, recommending 35 actions for the City to pursue. The plan actions are categorized into four key focus areas: people, climate, mobility systems and city function.

4.4 City of St. Louis (United States)

The *St. Louis Region Emerging Transportation Technology Strategic Plan (2017)*[20] was developed in response to the rapidly advancing technologies that are already disrupting the transportation industry and challenging policymakers involved in transportation planning and investment decision making. The plan consists of three major components: strategic goals; an analysis of Strengths-Weaknesses-Opportunities-Threats (SWOT); and recommendations related to policy areas of focus and implementation strategies to support positive outcomes for the region. The report considered the following emerging transportation technologies:

- ACE Vehicles;
- Ridesharing and Carsharing;
- MOD;
- MaaS;
- Technology-enabled freight applications and logistics (such as aerial drones);
- Advances in systems management and infrastructure including electronic payment methods, real-time traveler information, integrated corridor management, active transportation and demand management, social media/gamification, and advanced infrastructure;
- Shared Mobility; and
- Smart Cities.

Based upon the SWOT analysis and the expected and uncertain impacts of technology, the plan recommends the following areas of policy focus: safety, security, urban form and public transit, reliability, equity, freight and logistics, infrastructure preservation and maintenance, funding, and environmental quality. Recommendations to integrate emerging transportation technology into planning activities focus on improving institutional readiness, changes in the planning processes, and initiating pilot projects. Specific activities include: data modelling and analytics, long-range planning, programming and funding, pilot program development and education, convening, and supporting partner efforts. Implementing these activities are expected to maximize the benefits and reduce the risks of new technology, support innovation, and help the region to achieve its goals.

4.5 City of Melbourne (Australia)

Emerging Transport Technologies: Assessing Impacts and Implications for the City of Melbourne (2016)[21] explores the impacts and opportunities presented to the City by the rapidly advancing "disruptive transport" sector. The report describes current emerging transportation technologies as well as significant trends and future possibilities, providing the foundation for assessing the impacts and policy actions the City can take to harness emerging opportunities. The technologies examined in the report include:

- Car sharing, including new trends in one-way car sharing and peer-2-peer options;
- Ride sourcing applications (e.g. Uber);

- Car parking marketplace and revenue collection innovations;
- Multi-modal journey planning applications and smartphone payment options for transportation services of all modes; and
- Autonomous (driverless) vehicles and shared mobility compatibility.

The significant impacts identified from these technologies include:

- Greater use of ride sourcing services;
- Rising demand for car sharing;
- Lower demand for car parking;
- Greater demand for electric vehicle charging;
- Potential increase in congestion in the absence of additional congestion management measures; and
- Reduction in traffic collisions (long-term).

To best position the City to benefit from the opportunities created by emerging technologies, the report recommends actions aimed at: policy reform, third party engagement, ongoing research, government agreement, and other initiatives.

5 Recommendations

5.1 The Changing Landscape

Technological and social innovations are changing the way people access and think about transportation. What was previously an ownership-driven model is now transitioning to a service-based approach relying on a variety of transportation options for trip making instead of a singular travel mode. The impending arrival of connected and automated vehicles is also anticipated to dramatically reshape the transportation universe.

Positioning the City to leverage the benefits and opportunities presented by emerging trends and technologies will require ongoing efforts to maintain an understanding of evolving transportation options and refine strategies to apply these innovations. The strategies should comprise initiatives the City can undertake both on its own and in partnership with other agencies and entities, such as the Region of Waterloo. *Moving Forward – 2018 Transportation Master Plan* identifies the following eight policy directions to position the Region for new mobility[22]:

1. ***Integrate mobility services with public transit****, such as through a shared payment platform that would enable users to buy mobility on a variety of different modes. For example, through a smartphone app, users could plan trips and potentially purchase Grand River Transit credits, rent bicycles or cars, and ride taxis or Uber.*
2. ***Consider subsidized ride-hailing*** *through auxiliary taxi services such as Uber or Lyft, or conventional taxis, for areas of the Region with limited or no public transit.*
3. ***Consider rethinking how ride-hailing providers are regulated.*** *This includes both taxis and auxiliary taxis such as Uber and Lyft. Providers must be large enough to provide economies of scale but cannot be allowed to monopolize the mobility market.*

4. ***Examine on-demand and dynamically routed public transit service*** *that would enable transit services to modify existing routes based on demand. For example, Grand River Transit is already examining a pilot of an on-demand flexible service for customer satisfaction and service effectiveness.*
5. ***Investigate road user charging and other policies****, such as parking cost, to help manage demand, manage traffic congestion, and provide additional sources of revenue.*
6. ***Plan for a driverless ride-hailing pilot program*** *to learn how new technologies and delivery models for transportation can enhance mobility in the Region.*
7. ***Develop a New Mobility Action Plan*** *that includes specific objectives and actions to support the above initiatives.*
8. ***Update Regional Council annually*** *on any developments in the technology and staff's progress on the New Mobility Action Plan.*

Of these initiatives, it would be most appropriate for the City to explore collaboration with the Region on Directions 3, 5, 6, and possibly 7, considering the City's mandate, core responsibilities, and the directions of this TMP Update, The City could develop a New Mobility Action Plan (like Direction 7) on its own, as contemplated in Section 2.1 above, but working in partnership with the Region may offer greater benefit and opportunity for Waterloo residents given the potential scale and reach of a broader Regional initiative. An annual update to City Council, like Direction 8 above, should also be considered.

5.2 Looking Ahead

Based on the research completed, the following actions are recommended for the TMP Update. These actions may be undertaken by the City or in partnership with the Region (as noted above), surrounding municipalities, and/or a range of other potential public and private stakeholders interested in leveraging the ever-expanding list of emerging technologies and trends:

Shared Mobility

- Undertake a phased approach to adopting bike, car, and other modal (e.g. scooter) sharing opportunities
- Assess the potential for a Mobility as a Service (MaaS) system
- Develop a curb management strategy for meeting competing demands on curb space
- Explore the development of an Ecomobility Hub in the Uptown area

Automated, Connected and Electric Vehicles

- Permit the testing of low-speed automated vehicles in designated areas in the City
- Continue to establish publicly accessible vehicle charging infrastructure
- Continue to transition the city's fleet of vehicles towards electric and low carbon fuels if they meet functional needs
- Explore car parking reform, including real time information and dynamic pricing

- Develop planning strategies for the eventual repurposing parking lots and roadside on-street parking spaces

Smart Cities

- Explore expansion of City asset and information data sharing (e.g., open data) for use in facilitating technological development
- Consider developing a Smart City strategy

Supporting Initiatives

- Continue to monitor and research emerging transportation technologies and the impacts of new mobility trends
- Collaborate with universities, private industry, and all levels of government on various initiatives and pilot projects
- Conduct public education campaigns to communicate the benefits of new mobility models
- Build knowledge through staff attendance at key meetings and conferences
- Explore opportunities for participation in funding programs
- Develop/align city regulations, permits, and policies for new mobility

As noted above, the City should continue to proactively monitor and research emerging technologies through its strategic planning, including regular updates to the TMP. This will ensure the City:

- Maintains an understanding of emerging transportation technologies and trends and is not caught off guard when something new appears;
- Is aware of what it controls, the tools available to influence the technology or trend, and the responsibilities of other levels of government and industry. This allows the City to understand what influence it has over the technology and its adoption locally;
- Knows what other jurisdictions are doing in regard to regulating or promoting the technology or trend, so it can understand where it fits in relation to other jurisdictions and what innovative policies and practices it could utilize to influence the technology or trend;
- Can effectively assess the future impact of the technology or trends on the long-term vision articulated in its strategic policy documents;
- Develops an understanding of how future technologies and trends may impact City finances and steps it can take to be financially resilient; and
- Understands the potential impacts of the various technologies.

6 Impacts on Capital, Maintenance, and Operating Practices

It is difficult to predict the capital cost of implementing potential emerging technologies and responding to evolving trends as several initiatives noted in this report are still in the testing phase, are not in widespread use, and/or are not publicly available. **Table 1** summarizes the potential economic

opportunities and implications of these initiatives. Note that many of the impacts will only materialize once the technology is fully adopted and in effect.

The table suggests technology has the potential to significantly impact several existing revenue sources available to the City, including:

- **Fuel and Carbon Taxes** (both provincially and federally) – If electrification occurs as envisioned, the number of vehicles requiring gas and diesel fuel will decline, as will tax revenue;
- **Parking Revenue** – If parking options are more abundant for AVs, the price of parking will drop as vehicles will intelligently seek the lowest cost option;
- **Traffic and Parking Fines** – Assuming AVs abide with laws, traffic and parking infractions and related revenue will decline;
- **Changing Tax Base** – If AV deployment leads to greater urban sprawl, costs to expand and rehabilitate infrastructure could grow without corresponding increases to the property tax base. Conversely, if AVs enable the redevelopment of City parking lots for other uses, the tax base could increase.

While immediate action is not essential, the City should continue to monitor shifts in funding and explore potential alternatives to protect its fiscal position as conditions change. Services that rely on these funds will need to find alternate sources to continue. Consideration of impacts should be incorporated into long-term decision-making to align with the City's Long-Term Financial Plan and Asset Management Plan.

Unlike traditional means of travel, many emerging technologies need to continuously interact and take cues from their surrounding environment. In this future world, a well-maintained road system will be essential to ensuring these new technologies operate seamlessly and effectively. From the City's perspective, this may require more robust and resource intensive operations and maintenance practices. Additionally, as emerging technology advances, the City will need to be nimble and responsive, with the ability to quickly update practices and regulations to effectively accommodate rapid change.

Table 2 summarizes potential changes in maintenance and operating practices to consider based on the research. Most relate to increased maintenance expectations and growing big data management and network communication requirements.

7 Benefits Statement

Emerging transportation technologies and trends will have a profoundly transformative effect on cities, travel behaviour, and urban life. They also offer the opportunity to create greener, more prosperous communities that better balance growth demands with the need to maintain and enhance liveability. These desirable outcomes will not occur without the proper policy framework, though.

In addition to economic implications, **Table 1** lists likely benefits in health, environment, and cost of travel from introducing the technology. Anticipated negative impacts attributed to changes in employment, reduced physical activity, and increased social isolation are also stated. Again, many of the impacts noted in **Table 1** will only materialize once the technology is fully adopted.

Table 1: Potential Implications of Different Transformative Technologies
(Source: City of Calgary, 2017)

Technology	Fiscal		Social		Environmental		Socio-Economic	
	Opportunities	Impacts	Opportunities	Impacts	Opportunities	Impacts	Opportunities	Impacts
Automated Vehicles – Personal (Private) and Shared Vehicles	• May reduce the need for capital investments if capacity increases are realized once system fully autonomous. • May be an opportunity to move towards a fuller user-pay system on the road network. • Decreased collisions should reduce demands on fire and police resources. • There might be an increase in roundabouts or traffic circles and reduction in signalling once AVs have a high market saturation.	• Will require improved maintenance of some assets (such as lane markings) and services such as snow clearing depending on technology. • May require more investment in GIS mapping of certain assets and provide real time data on any network disruption such as lane closures for construction or maintenance. • May reduce revenues from traffic infractions. • May reduce revenues from parking fees and infractions.	• Personal AVs provide significant opportunities to augment current travel options for those who are not able to drive, such as seniors, children, and individuals with disabilities. • Should dramatically reduce injuries and deaths from motor vehicle collisions, which would have significant health benefits. • Impaired driving unlikely to be a future concern with Level 4-5 AVs.	• Increased use of AVs at the expense of more active travel modes could result in negative health impacts on the population. • Viable organ donors could be reduced, as many organ donations are obtained from victims of motor vehicle collisions.	• Likely have less energy consumption relative to traditional vehicles, through improved driver behavior and lighter vehicle design. • May be designed to be more easily recycled. • The reduction in collisions would reduce waste from damaged vehicles and property.	• Mass adoption would accelerate the replacement of the existing vehicle fleet, which would need to be disposed of or recycled. • Increased travel may have some environmental impacts. • The potential for sprawl generated from the flexibility of AVs could have significant environmental impacts.	• Travel costs are likely to be reduced for citizens and businesses. • Businesses may find opportunities to incorporate advertising into the vehicles. • There may be increases in tourism and productivity as people could travel further in their vehicles without driving and could incorporate sleeping and other activities in the vehicle as it takes them to their destination.	• Reduced labour needs could result in negative impacts on job availability, particularly in for-hire vehicles and fleet vehicles. • If tolls are introduced to help fund infrastructure, this would be a new fee for travellers. However, this may be somewhat offset by the disuse of fuel tax as a revenue tool if the fleet electrifies.
Automated Vehicles – Public Transit	• Will reduce labour costs, depending on the technology and its ability to meet the broader customer service objectives. • Some jobs could be reallocated from drivers to customer service agents.	• Reduced labour needs could result in negative impacts on job availability.	• There could potentially be increased customer service if resources previously directed to drivers are redirected to this area. • The greater mix of transit options (such as different vehicle types) can help people with unique travel needs. • Safety of the system would be further increased through automation.	• If there is less public transit service because of travellers shifting to other travel options, there may be reduced social activity that results from the use of public transit (e.g., increased isolation).	• The public transit fleet may be more “right-sized” to the demand, which could reduce environmental impacts.	• Reduced public transit usage could have environmental impacts if the public switches to personal vehicles.	• It is possible that increased automation could reduce transit fares.	• Reduced labour needs could result in negative impacts on job availability.
Automated Vehicles – Goods and Freight	• Platooning and further automation of goods movement may reduce overall network congestion and reduce capital investment needs.	• Reduced labour needs could result in negative impacts on driving jobs.	• The ease of obtaining goods should be improved.	• There could be increased social isolation due to a reduced need to go to stores (e.g., robot delivery units).	• Fewer collisions may result in less damage to property, including damage from spilled goods.	• The lack of a driver could result in response challenges if an environmental incident were to occur (e.g., spill).	• Platooning and further automation of goods movement may help bring down costs. • Faster delivery of goods could lead to higher efficiency for businesses. • A broader range of goods may be available. • Assuming improved compliance with vehicle weight restrictions, rate of pavement deterioration would be reduced.	• Reduced labour needs could result in negative impacts on driving jobs.

Table 1: Potential Implications of Different Transformative Technologies
(Source: City of Calgary, 2017)

Technology	Fiscal		Social		Environmental		Socio-Economic	
	Opportunities	Impacts	Opportunities	Impacts	Opportunities	Impacts	Opportunities	Impacts
Connected Vehicles	• In longer term, some infrastructure such as signs and signals may only be provisioned virtually.	• May require infrastructure investment at signals and other control devices if V2I becomes common.	• The enhanced safety resulting from CVs would have positive health benefits.	• No significant negative social impacts have been identified.	• CVs will increase the efficiency of travel, which can have positive benefits.	• No significant negative environmental impacts have been identified.	• If vehicles can move more efficiently through connectivity, this may result in reduced travel times for the public. • Connectivity may help reduce collisions which would reduce the associated costs with collisions.	• Initially, there may be a cost premium for these features.
Electric Vehicles	• May increase electricity sales and revenues for utilities. • Once tested in local conditions, may reduce operating and maintenance costs for fleet vehicles. • Required changes to the distribution and local storage network is an opportunity to improve resiliency. • Noise attenuation may no longer be necessary.	• Will reduce revenues from existing fuel taxes that currently fund infrastructure. • May want to provide funding for charging stations in some circumstances. • Utilities may incur costs upgrade elements of the electrical distribution system. • May need to deal with the disposal of used batteries.	• No significant social opportunities identified.	• No significant negative social impacts have been identified.	• The use of electric vehicles will have a positive impact on emissions reduction. This result is further improved if the power grid fuel sources are changed to reduce GHG at the point of generation. • Noise pollution is likely to be reduced.	• If traditional fuel stations are abandoned, there will be an increase in sites requiring environmental reclamation before being repurposed. • Where vehicles are stored (i.e. home locations), there may be an increase in land dedicated to parking as to facilitate vehicle charging if it is not done on-street. • There could be a significant increase in battery waste products.	• In the long term, it is expected that electric vehicles will cost less to own and operate than gas or diesel fuelled vehicles, which will result in savings for the public.	• Jobs in the traditional vehicle field would need to transition to the electric vehicle field. This could include more focus on computer systems and less on mechanical ones. The nature of vehicle maintenance may change.
E-Bikes	• More people cycling could reduce the need for extra roadway and transit infrastructure.		• E-bikes should increase the mobility of groups such as seniors, providing an additional travel option.	• No significant negative social impacts identified.	• E-bikes would increase the attractiveness of cycling, which would have environmental benefits for those who switch from traditional automobiles.	• There would be a resulting battery waste stream produced.	• E-Bikes would increase the attractiveness of cycling trips, which can be more cost-effective relative to driving.	• No significant negative economic impacts identified.
Internet of Things	• In some circumstances, sensors may replace manual monitoring and improve service efficiency. • Energy saving for streetlights. • Air health monitoring.	• Provision and maintenance of sensors would be a new cost. • Data security for devices will be a new cost.	• People are more connected digitally. • May allow for more targeted marketing and provision of transportation services. • Ability to obtain more information to inform travel decisions.	• Increased connectivity will increase privacy and security concerns for the public. • Increased targeted marketing may become a nuisance.	• The use of sensors in certain applications may help reduce waste (e.g., plants that have died, assets that are damaged, etc.) by better directing resources.	• More products may have electric components attached to them in the waste stream.	• The availability and use of sensors may help reduce labour costs for activities that currently require manual checking. • The collection of data could lead to new economic opportunities for business and improved marketing.	• No significant negative economic impacts identified.

Table 1: Potential Implications of Different Transformative Technologies
(Source: City of Calgary, 2017)

Technology	Fiscal		Social		Environmental		Socio-Economic	
	Opportunities	Impacts	Opportunities	Impacts	Opportunities	Impacts	Opportunities	Impacts
Shared Mobility/ Mobility as a Service	• May offer a more cost-effective method for providing some current transit services or allow for new, additional services that were not previously cost effective. • Various MaaS services could feed into the transit network. • May need to consider charges for loading activities in congested areas.	• Will put significant downwards pressure on parking revenues. • May reduce revenues for transit, particularly if profitable routes have more competition. This could impact the fare-to-subsidy ratio.	• People have more mobility options and reduces travel as a barrier. • Impaired driving less likely with more mobility options (e.g., people can use a TNC for a ride home from the bar.)	• No significant negative social impacts identified.	• Better matching vehicles with services will result in a better usage of existing vehicles, which would reduce the total vehicle fleet (and resources used to produce the fleet).	• No significant negative environmental impacts identified.	• The provision of on-demand services should reduce car ownership, which would result in savings to individuals who forego potential vehicle purchases.	• The nature of employment may change, from full-time drivers to more casual drivers or automation.
Parking Technologies	• There could be opportunities for further marketing with respect to AV integration, and some electric vehicle charging. • Technology may facilitate additional parking transactions, which could increase revenue. • Existing parking facilities may be more efficiently used if cars can become packed more densely due to automation. • Less expenditure on land for parking.	• Existing parking structures may not have the structural capacity to handle additional vehicle weight from more dense parking. • Challenge to integrate various parking providers into a common and seamless payment technology.	• No significant social opportunities identified.	• No significant negative social impacts identified.	• Better parking information systems will help reduce unnecessary travel resulting from searching for parking.	• Parking structures that are no longer useful may end up being demolished. Underground parking may struggle to be repurposed in some cases.	• PayBySky solutions will help reduce spending on parking by only charging for actual parking use. • Parking fees in high-demand areas are expected to drop since vehicles may park outside of these areas.	• Some parking solutions may enable additional abilities for paid parking.
Unmanned Aerial Systems (Drones)	• If proliferate for deliveries, may move some traffic off the road system, which could reduce congestion and infrastructure investment.	• If proliferate, there may be new costs for drone enforcement.	• The ease of obtaining goods should be increased.	• There could be increased social isolation due to a reduced need to go to stores (e.g. robot delivery units).	• Drones may be able to identify conditions on the transportation system more quickly.	• Drones may cause increased noise and visual pollution.	• Drones may increase economic activity by providing a new delivery solution that may be more cost effective in some cases.	• It is unclear if there may be an increase in issues related to damage from drones (e.g., dropped cargo, drone collisions, etc.).

R Table 2: Maintenance and Operating Considerations for Different Transformative Technologies

Technology or Trend	Maintenance	Operating
Shared Mobility	• Increased maintenance level of service (i.e. bike lanes, multi-use trails, sidewalks, designated parking spaces, bike racks, crossings) especially during winter months. This has the potential to significantly increase cost. • Provincial legislation largely governs maintenance standards, which may impact the City's ability to meet community expectations. The City may need to advocate for legislative changes to serve requirements.	• Need to manage and enforce curb and boulevard space restrictions (e.g., parking for e-scooters, bikes, ride share) • Potential opportunity to repurpose roadway for pedestrians, cyclists and other shared modes through line marking and signs • Need to gather and manage "big data" (e.g., database systems, sensors, data security, network communications, applications) • Need for improved traveller information, for which the City may play a role in serving (e.g., parking occupancy in City-owned garages)
Automatic, Connected, and Electric Vehicles	• Increased maintenance level of service (i.e. snow and ice removal, inspections, vegetation removal, pavement markings, traffic signals, traffic signs) especially during heavy rain or snowfall events • May necessitate new or different equipment functionality to satisfy emerging requirements	• Need to manage and enforce curb space restrictions (e.g., pick-up/drop-off zones, restricted zones) • Reduced incident response and clean-up times • Need to gather and manage "big data" (e.g., database systems, sensors, data security, network communications, traffic control systems)
Smart Cities	• Increased maintenance level of service (i.e. networks, communication systems) and reliance on third party, offshore services	• Need for improved broadband internet coverage and higher transfer speeds • Need to upgrade infrastructure to accommodate 5G technology • Need to gather and manage "big data" (e.g., database systems, sensors, data security, traffic control systems) • Need for improved traveller information • Need for more data collection and monitoring (e.g., ensure City can adapt as needed)

Municipalities do not want to be in the position where a transportation technology is beginning to be adopted by the public and there is uncertainty as to how/if it should be regulated, and how it fits into their strategic plans. Conversely, cities do not want to overregulate a technology too early, potentially negating its benefits, or invest prematurely in infrastructure for a technology that may not be embraced by its citizens (e.g., rollerblades, segways). By staying informed of emerging technologies and trends, the City will be well positioned to benefit from these developments.

Several technologies identified in this report are in the testing phase and/or are not readily available to the public yet. It may take years after the technology is adopted to fully understand the implications to society and the built form. Being on the cutting edge of technology can brand the City as being progressive, allow the municipality to offer services other jurisdictions cannot, and sometimes foster job creation. This also comes with an increased cost and risk of failure as new technologies are trialed and implemented. Alternately, Waterloo can monitor what other municipalities are doing globally and learn from their successes and failures. The best approach for the City is to be a leader in fields of existing strength, such as shared mobility related to active transportation and sustainable mobility, while monitoring the evolution of other emerging technologies, like ACE vehicles and Big Data, in communities outside Waterloo. This will ensure the City can fully leverage benefits gained from investing in new technologies while minimizing potential risk.

8 References

1 Cohen, Adam. “How Technology Will Shape Transportation in Smart Cities”. https://www.smartcitiesworld.net/opinions/opinions/how-technology-will-shape-transportation-in-smart-cities [Accessed June 12, 2020].

2 Transportation Research Board. *Transportation Research Circular E-C208, Transformational Technologies in Transportation: State of Activities.* National Academies of Sciences, Engineering, and Medicine. Washington, DC. May 2016.

3 Federal Highway Administration. *Shared Mobility: Current Practices and Guiding Principles*. Washington, DC. April 2016.

4 Transportation Research Board. *National Cooperative Highway Research Board Research Report 924, Foreseeing the Impact of Transformational Technologies on Land Use and Transportation*. National Academies of Sciences, Engineering, and Medicine. Washington, DC. 2019.

5 Chappelow, Jim. “Sharing Economy”. https://www.investopedia.com/terms/s/sharing-economy.asp [Accessed May 29, 2020].

6 Federal Highway Administration. *Mobility on Demand: Operational Concept Report*. Washington, DC. September 2017.

7 MaRS Discovery District and Arup. *Mobility as a Service: The Value Proposition for the Public and Our Urban Systems.* Toronto, ON. March 2018.

8 Abel, Sarah.” Mobility and the Public Right of Way”. ITE Journal. Institute of Transportation Engineers. Washington, DC. June 2019.

9 Shaheen, Susan and Adam Cohen. “Similarities and Differences of Mobility on Demand (MOD) and Mobility as a Service (MaaS)”. ITE Journal. Institute of Transportation Engineers. Washington, DC. June 2020.

10 Federal Highway Administration. *Shared Mobility: Current Practices and Guiding Principles.* Washington, DC. April 2016.

11 Council of Ministers of Transportation and Highway Safety, Policy and Planning Support Committee (PPSC) Working Group on Automated and Connected Vehicles. *Automated and Connected Vehicles Policy Framework for Canada*. Ottawa. January 21, 2019.

12 Ontario Ministry of Transportation. *CAV Readiness Plan, Final Report*. March 2020.

13 According to the website PlugShare. https://www.plugshare.com/ [Accessed June 3, 2020].

14 Canadian Urban Institute. *Smart Planning Our Smart Cities: A Best Practices Guide for Building Our Future Cities*. June 2018.

15 Transportation Research Board. *National Cooperative Highway Research Board Research Report 924, Foreseeing the Impact of Transformational Technologies on Land Use and Transportation*. National Academies of Sciences, Engineering, and Medicine. Washington, DC. 2019.

16 https://www.toronto.ca/services-payments/streets-parking-transportation/automated-vehicles/automated-vehicles-background/ [Accessed June 12, 2020]

17 https://www.toronto.ca/services-payments/streets-parking-transportation/automated-vehicles/automated-vehicles-background/ [Accessed June 12, 2020]

18 https://www.calgary.ca/transportation/tp/strategy/future-of-transportation-in-calgary.html [Accessed June 12, 2020]

19 https://www.edmonton.ca/city_government/initiatives_innovation/smart-transportation-action-plan.aspx [Accessed June 12, 2020]

20 https://www.ewgateway.org/wp-content/uploads/2017/08/emergingtranstechstratplan.pdf [Accessed June 12, 2020]

21 https://www.melbourne.vic.gov.au/parking-and-transport/public-transport/Pages/emerging-transport-technologies.aspx [Accessed June 12, 2020]

22 Region of Waterloo. *Moving Forward – 2018 Transportation Master Plan*. June 2019. p. 5-45

15 ACTIVE TRANSPORTATION INTERSECTIONS AND CROSSINGS

TRANSPORTATION MASTER PLAN
LOOKING AHEAD

THE CITY OF Waterloo

Date: April 28, 2020

To: Chris Hodgson, City of Waterloo

From: Ezra Lipton, Alta Planning + Design

Cc: Kate Whitfield, Alta Planning + Design

Matt Pinder, Alta Planning + Design

Nataliya Pekar, Alta Planning + Design

Gene Chartier, Paradigm Transportation Solutions

Re: **Waterloo TMP – Active Transportation Intersections and Crossings**

Introduction

This memo explores design improvements to intersections and crossings with active transportation facilities based on engineering and user design best practice.

Part A of the memo includes concepts of intersection and crossing designs at five locations in the City of Waterloo that were identified by the consulting team and City staff. These high-level concepts present ultimate reconstruction conditions and illustrate design and engineering principles and best practices. The concepts are also resources intended to provide City staff with the tools needed to design improvements to other intersections and crossings in Waterloo.

Part B of the memo includes a summary of intersection and crossing countermeasures split into **short-term and long-term. Short-term** countermeasures are intended to be low-cost and easy to implement, while **long-term** countermeasures are to be considered when improvement opportunities arise through reconstruction.

Part A – Concepts

The concepts presented in this memo are high-level and illustrative in nature. The widths and geometries of the roadway elements shown are based on standard widths from the *Ontario Traffic Manual Book 18: Cycling Facilities* (2013). The concepts were developed based on a variety of assumptions detailed below. The locations for which concepts were designed are:

- Lexington Road and Davenport Road
- Phillip Street and Columbia Street West
- Conservation Drive and Westmount Road
- Keats Way and Westfield Trail
- University Avenue East and Millennium Boulevard

Assumptions and Methodology

- Existing vehicle lane widths and configurations are generally maintained, except where otherwise noted.
- Where existing corner radii and/or effective turning radii for vehicles is determined to be excessive, it is lowered through the design to the range of 12-15 metres. Autoturn analysis should be used to confirm that the concept geometry is suitable for the desired design and control vehicles.
- Existing and/or future traffic volumes and speeds were not available and therefore were not factored into the designs. The operating speed is assumed to be the same as the posted speed.
- A consistent approach is taken to separate pedestrians and cyclists at intersections, even when they are mixed on approaches. Separating these users minimizes potential for conflicts and future-proofs intersection designs for the potential of separating users mid-block (such as a sidewalk adjacent to a cycle track).

Lexington Road and Davenport Road

The existing condition for Lexington and Davenport is shown in the aerial below (Figure 1). Improvements in the concept design include removing the westbound floating bike lane on Lexington and improving conditions at the right turn channel.

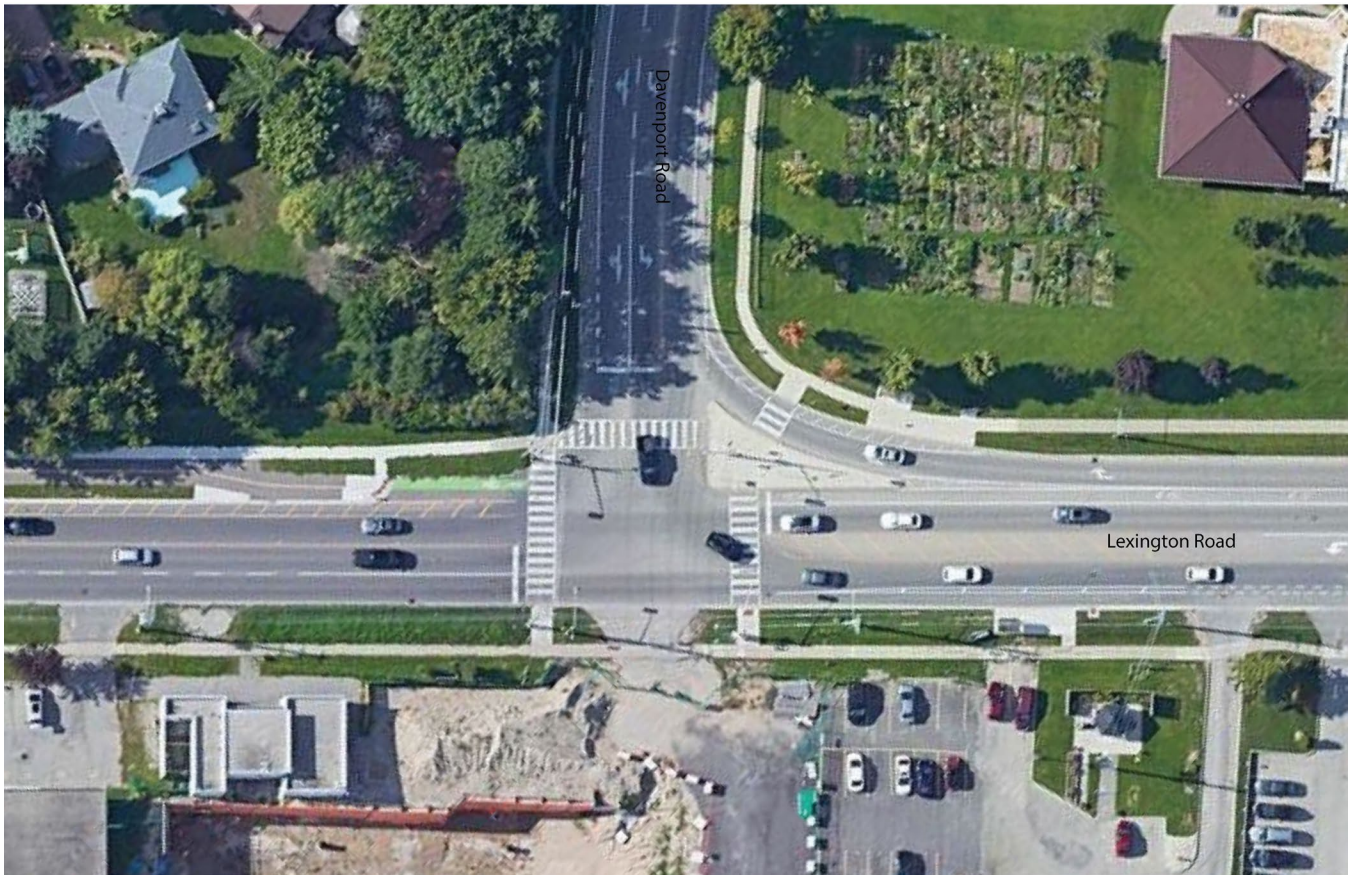


Figure 1. Existing conditions of Lexington and Davenport

The following are design interventions applied to this intersection (shown in Figure 2):

- On the westbound approach, the existing "floating" bike lane has been relocated to the curb where it transitions into the boulevard at the intersection. This allows cyclists to either cross the right turn channel perpendicularly, or continue northbound (transitioning back to the existing on-street bike lane) without a motor-vehicle conflict at the channel.
- On the southbound approach, the existing on-street bike lane transitions into a cycle track, leading to a protected corner. From there, southbound cyclists can continue westbound via the bidirectional cycle track or eastbound via a two-stage crossing. The eastbound departing cycle track would transition back to the existing on-street buffered bicycle lane east of the intersection.
- On the eastbound approach, the existing bidirectional cycle track is continued to the intersection to meet the protected corner. Cyclists can continue northbound via the bidirectional crossride on the north side, then crossing the right turn channel.
- A raised crossing is applied on the right turn channel to reduce vehicle speeds and increase yielding rates.
- Two-stage pedestrian crossings are provided where pedestrians cross cycle tracks and vehicle lanes.
- The existing westbound bus stop is relocated to the far side of the intersection. The existing eastbound stop is maintained in the current location.

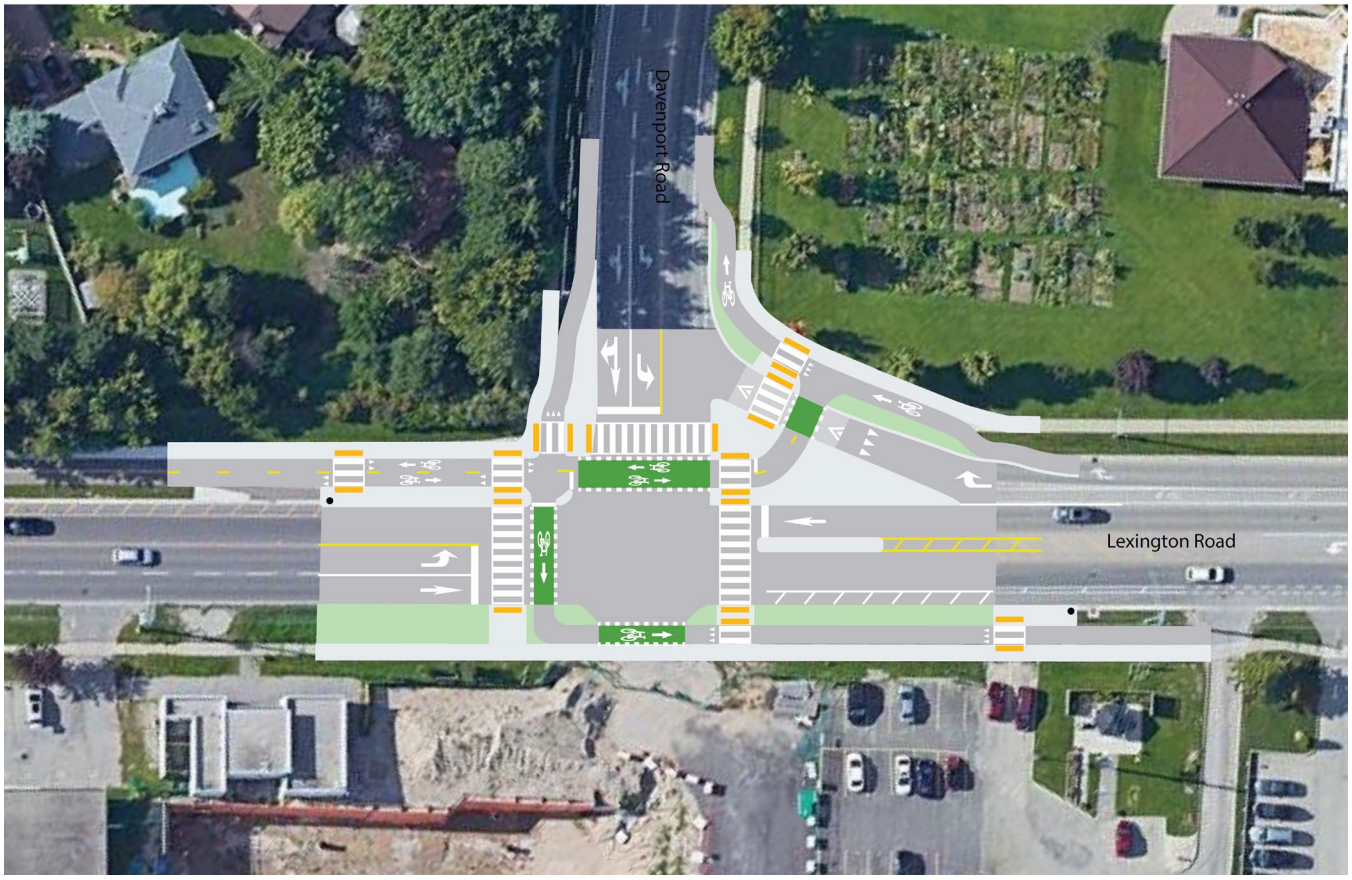


Figure 2. Concept design of Lexington and Davenport

Further considerations:

- Given the presence of the bidirectional crossride on the north leg, a fully-protected eastbound left for motorists should be considered to minimize the potential for conflict. The MassDOT Separated Bike Lane Planning & Design Guideline suggests that a fully-protected left turn phase be considered when left turning vehicle volume exceeds 50 per hour (for left turns on two-way street across one traffic lane and a bidirectional cycling facility).
- The concept design is compatible with a fourth leg being added to the intersection in future, if such a treatment is planned.

Phillip Street and Columbia Street West

The existing condition for Phillip and Columbia is shown in the aerial below (Figure 3). Improvements in the concept design include conversion to a protected intersection with full separation of road users.

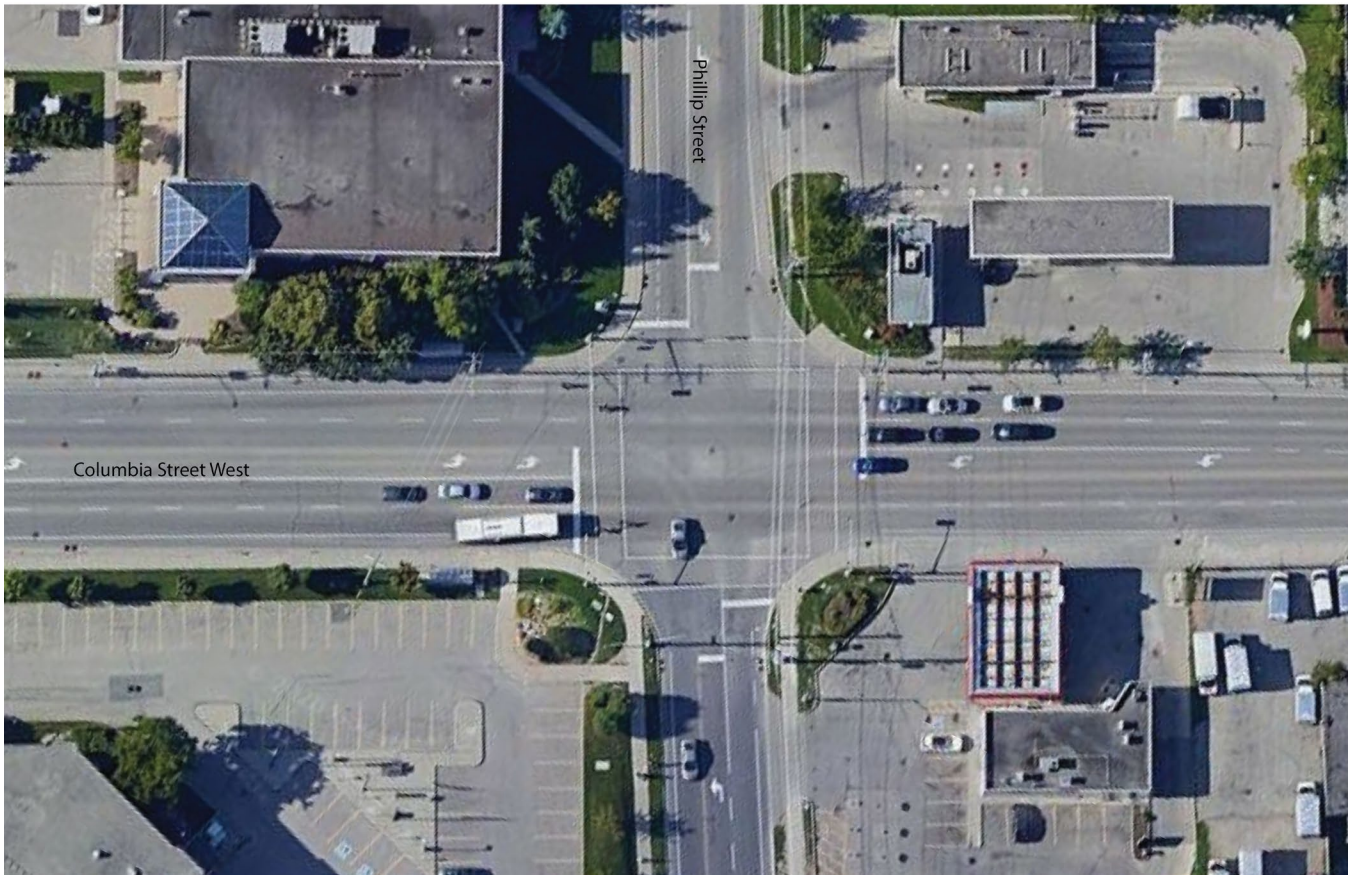


Figure 3. Existing conditions of Columbia and Phillip

The following are design interventions applied to this intersection (shown in Figure 4):

- On all approaches, existing on-street bicycle lanes transition to cycle tracks, allowing right-turning cyclists to bypass the intersection via protected corners. The configuration also better manages through-bound cyclists from turning vehicle conflicts and allows left-turning cyclists to comfortably traverse the intersection in two-stages.
- The planned MUP on the east side of Phillip and north of the intersection is incorporated into the design. On the intersection approach, the MUP splits into a sidewalk and cycle track, allowing comfortable and predictable separation of users through the intersection.
- Two-stage pedestrian crossings are generally provided to reduce the pedestrian crossing distances.
- The concept design provides roughly 12-metre physical radii on all corners.
- The eastbound near-side bus stop is accommodated in the design as an island bus stop between the cycle track and the roadway. This design mitigates conflicts between cyclists, transit vehicles, and pedestrians.

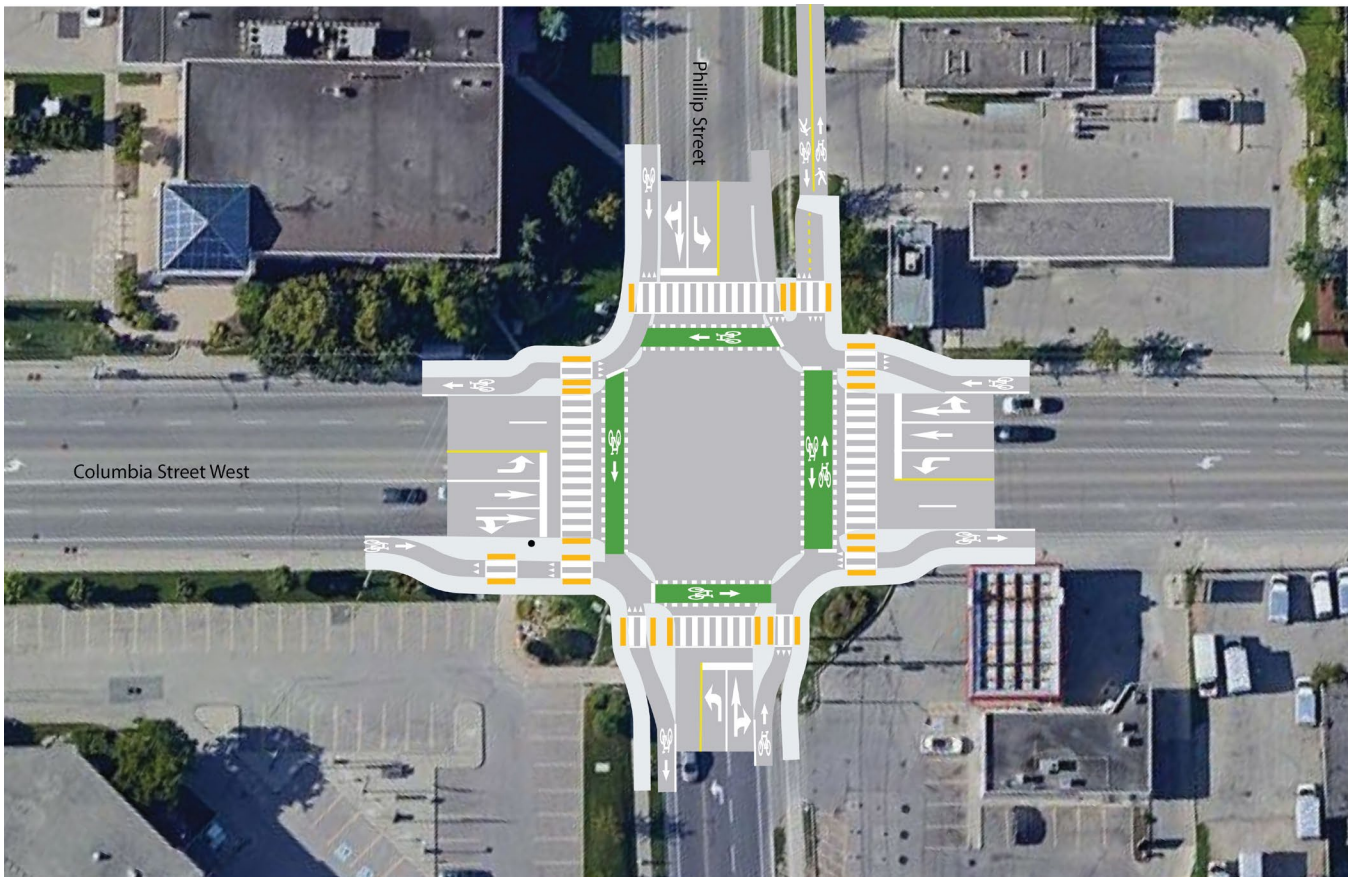


Figure 4. Concept design of Columbia and Phillip

Further considerations:

- This design is compatible with a future conversion of the on-street bicycle lanes on Columbia to raised cycle tracks, which is a more suitable facility type based on the traffic volumes and speed characteristics of the roadway.

Millennium Boulevard at University Avenue East

The existing condition at Millennium and University is shown in the aerial below (Figure 5). The concept design accommodates the complex arrangement of existing and planned facilities at the intersection, including a west-side MUP and on-street bike lanes on the north leg, on-street bike lanes eastbound and westbound, a north-side MUP on the east leg, and a trail connection on the south leg.

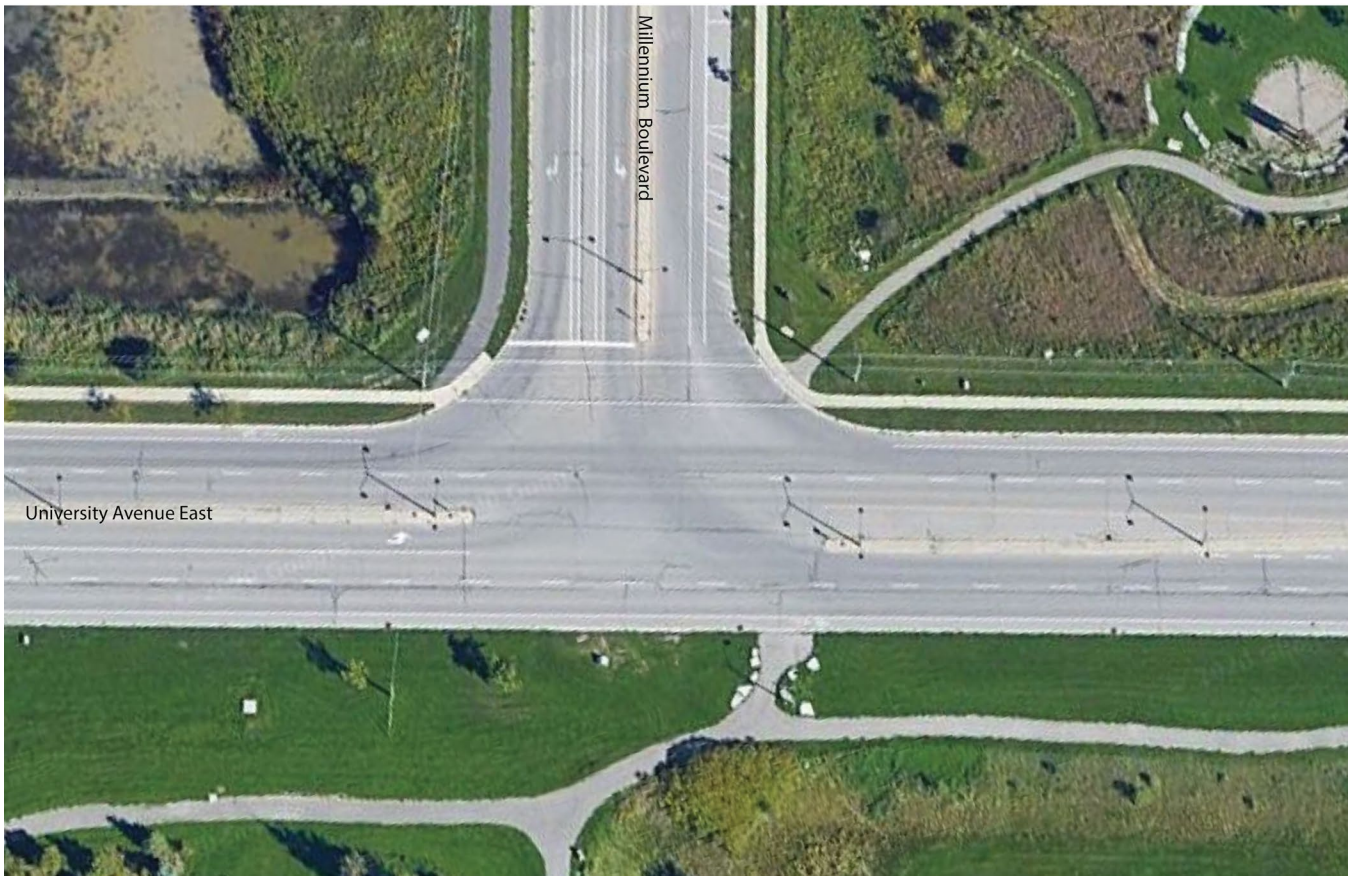


Figure 5. Existing conditions of University and Milllennium

The following are design interventions applied to this intersection (shown in Figure 6):

- Protected corners are provided, separating pedestrian, cyclist, and motorist movements through the intersection. MUPs are split into sidewalk and cycle track on each approach.
- On all approaches, existing on-street bicycle lanes transition to cycle tracks, allowing right-turning cyclists to bypass the intersection, separating through-bound cyclists from turning vehicle conflicts, and allowing left-turning cyclists to comfortably traverse the intersection in two-stages. Eastbound cyclists fully bypass the traffic signal.
- On the southbound approach, the existing buffered floating bike lane is relocated to the curb to mitigate the need for cyclists to cross traffic lanes on the intersection approach.
- Although the future projected southbound vehicle volumes were not specified, it is assumed that a second southbound left turn lane will be added in future. The design incorporates this second southbound left turn lane, but is not contingent upon it. Because of the potential for a future dual-left

turn, a bidirectional crossride is on the west leg rather than the east to avoid the need for separate signal phases.

- The concept design provides roughly 12-metre physical radii on all corners, equating to effective turning radii of 15-metres when taking into account the dual receiving lanes for right-turning vehicles.

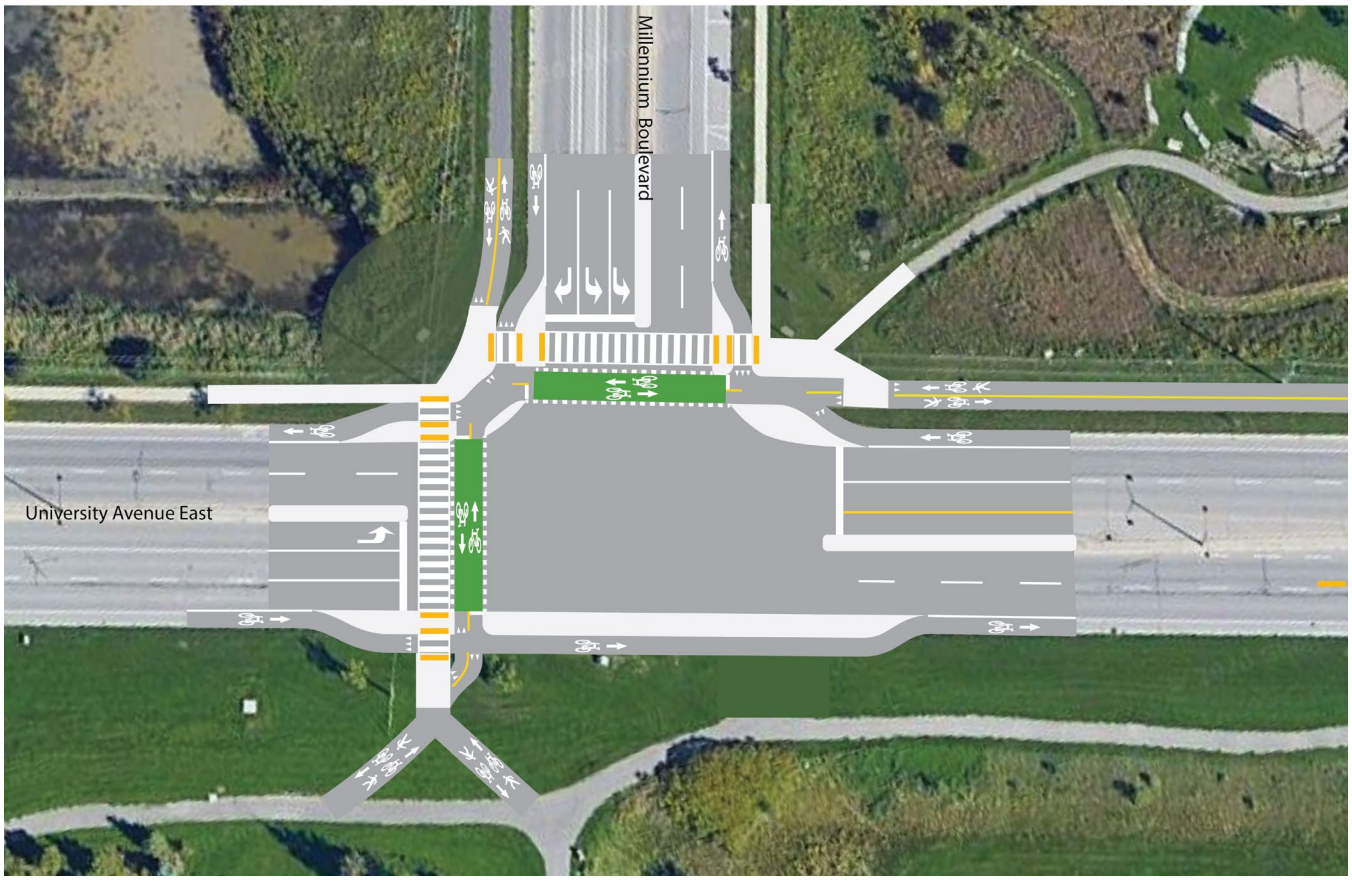


Figure 6. Concept design of University and Millennium

Further considerations:

- Due to the high potential for conflicts with the bidirectional crossride on the north leg, it is strongly recommended that the eastbound left turn signal be fully protected.

Keats Way at Westfield Trail

The existing condition at Keats and Westfield is shown in the aerial below (Figure 7). The concept design seeks to provide a comfortable crossing environment for users of the Westfield Trail that minimizes potential for conflict.

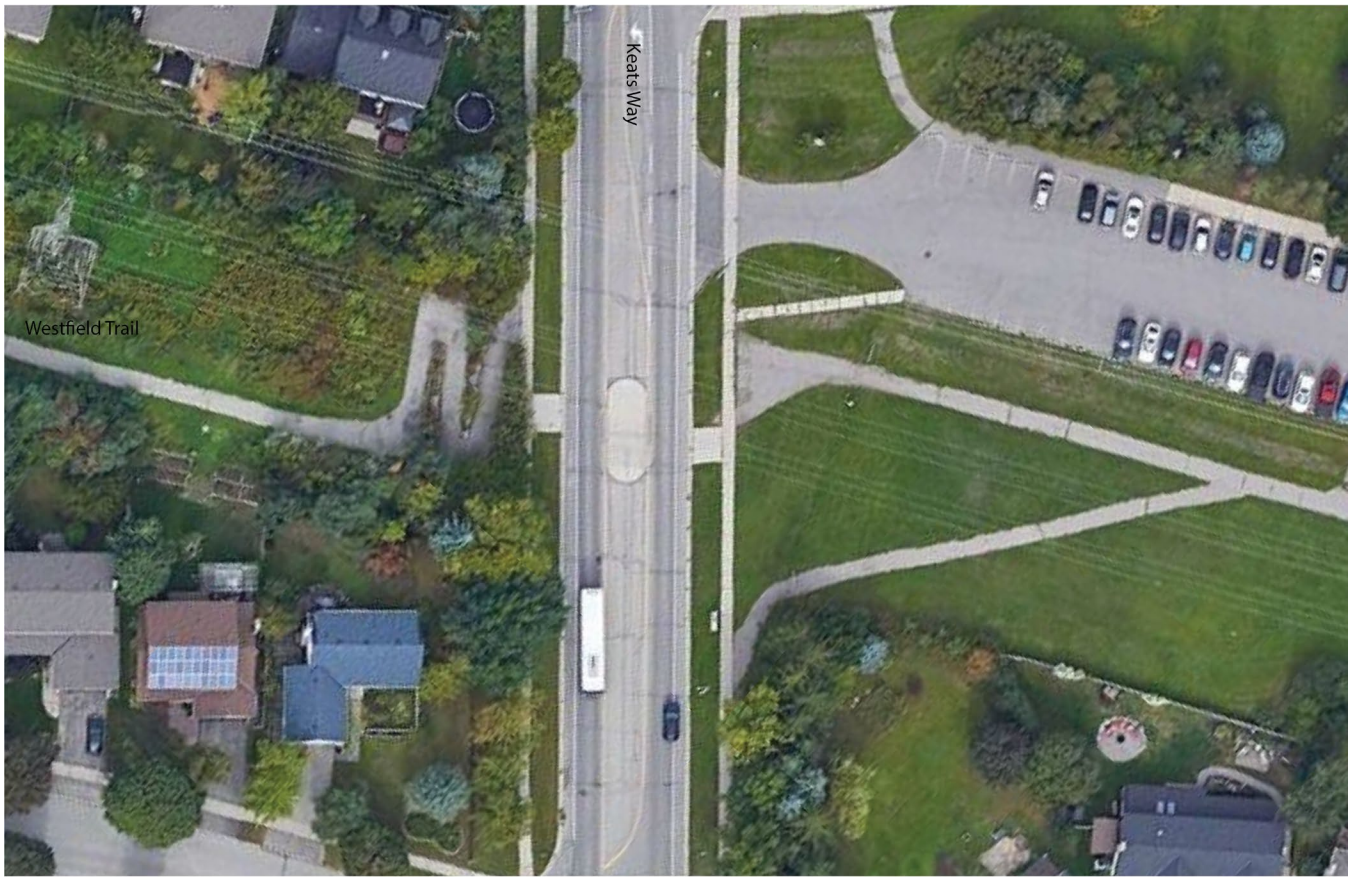


Figure 7. Existing conditions of Keats Way and Westfield Trail

The following are design interventions applied to this crossing (shown in Figure 8):

- To reduce motor vehicle speeds on the approach to the crossing, lanes are tapered inward at a 1:8 ratio (matching a design speed of 40-50km/h), and the crossing is raised to achieve a target speed of 30 km/h approaching the crossing to improve yielding compliance.
- Bike lanes become raised cycle tracks through the crossing. Pedestrians cross via a two-stage crossing to reduce crossing length. Because of the bumped-out crossing, pedestrians are more visible to oncoming motorists, especially southbound motorists coming around the curve in the roadway.
- The required stopping sight distance of the crossing has been confirmed for a design speed of 50 km/h.
- A pedestrian cross-over (PXO) is added to the crossing to improve safety for vulnerable road users, especially children traveling to school. The type and level of control depend on the vehicle volume of the roadway which were not known at the time the design was produced. At present, cyclists in Ontario cannot legally ride across a PXO and therefore must dismount and cross as pedestrians.
- The trail on the west side has been modified to provide an alignment and grade change more comfortable for cyclists. The approximated grade change from Google Earth is 5 metres and the target

grade is 5%, resulting in a sloped path of 100 metres. Curve radii of 7 metres are used on the path, a radius that allows cyclists to ride comfortable and smoothly while upright. A more direct alternate route may be provided for able-bodied pedestrians via stairs. A comparable design can be found in Ottawa outside of the Ottawa U LRT station.

- The trail is modified to meet the roadway at the point of crossing to provide a more direct path for pedestrians and cyclists.

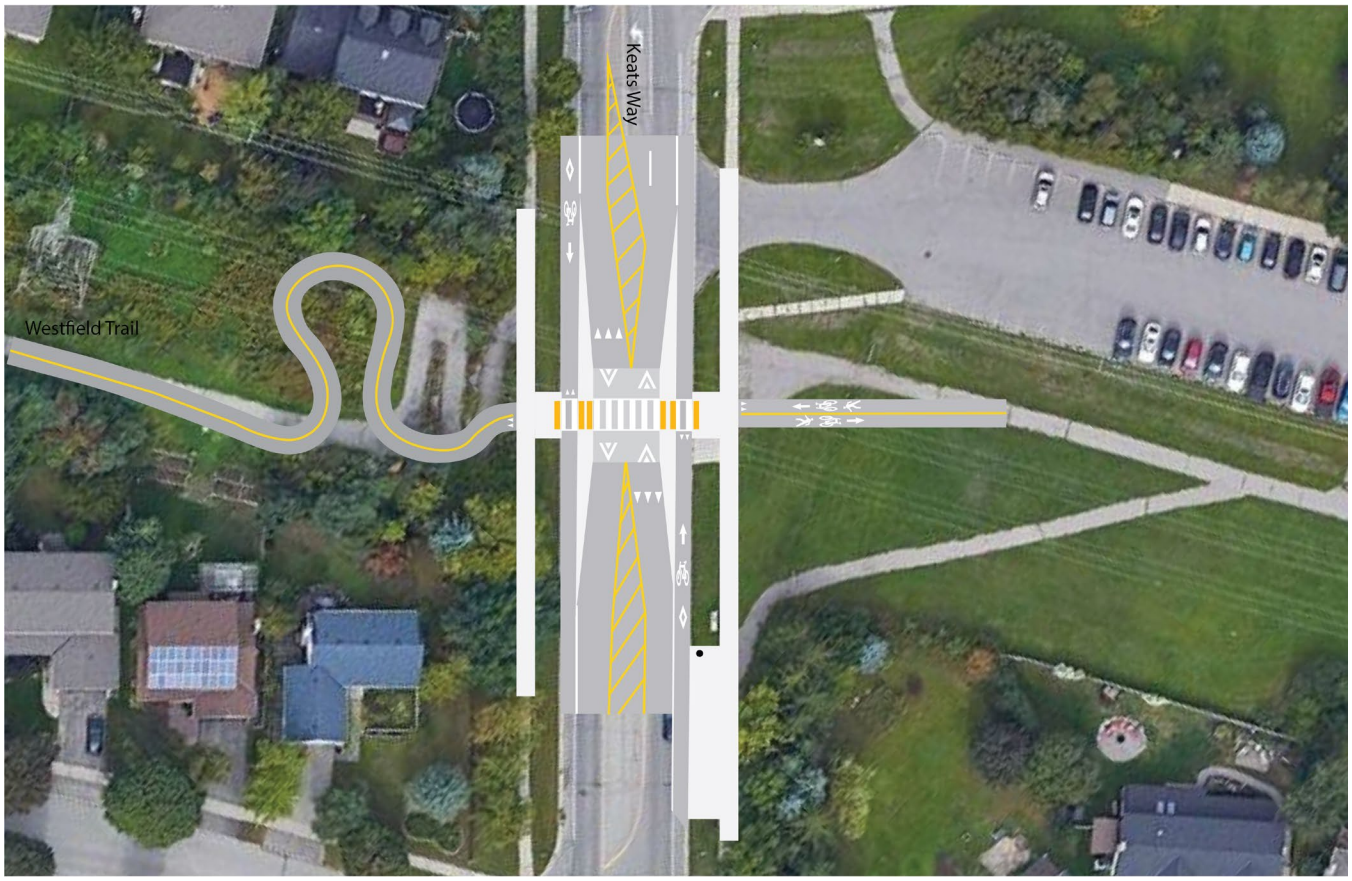


Figure 8. Concept design of Keats Way and Westfield Trail

Further considerations

- The average daily traffic and average motor vehicle travel speed were not provided as part of the design, both of which are important factors in determining PXO suitability and control type.
- Although cycling through a PXO is currently not legal in Ontario, evidence from other jurisdictions such as Quebec suggest that this may change in the future. The design protects for a future separate crosswalk/crossride by providing a raised portion that is 6 metres wide.

Conservation Drive and Westmount Road

The existing condition at Conservation and Westmount is shown in the aerial below (Figure 9). The concept design for Conservation and Westmount connects the existing MUP on Westmount with a planned MUP on the south side of Conservation.

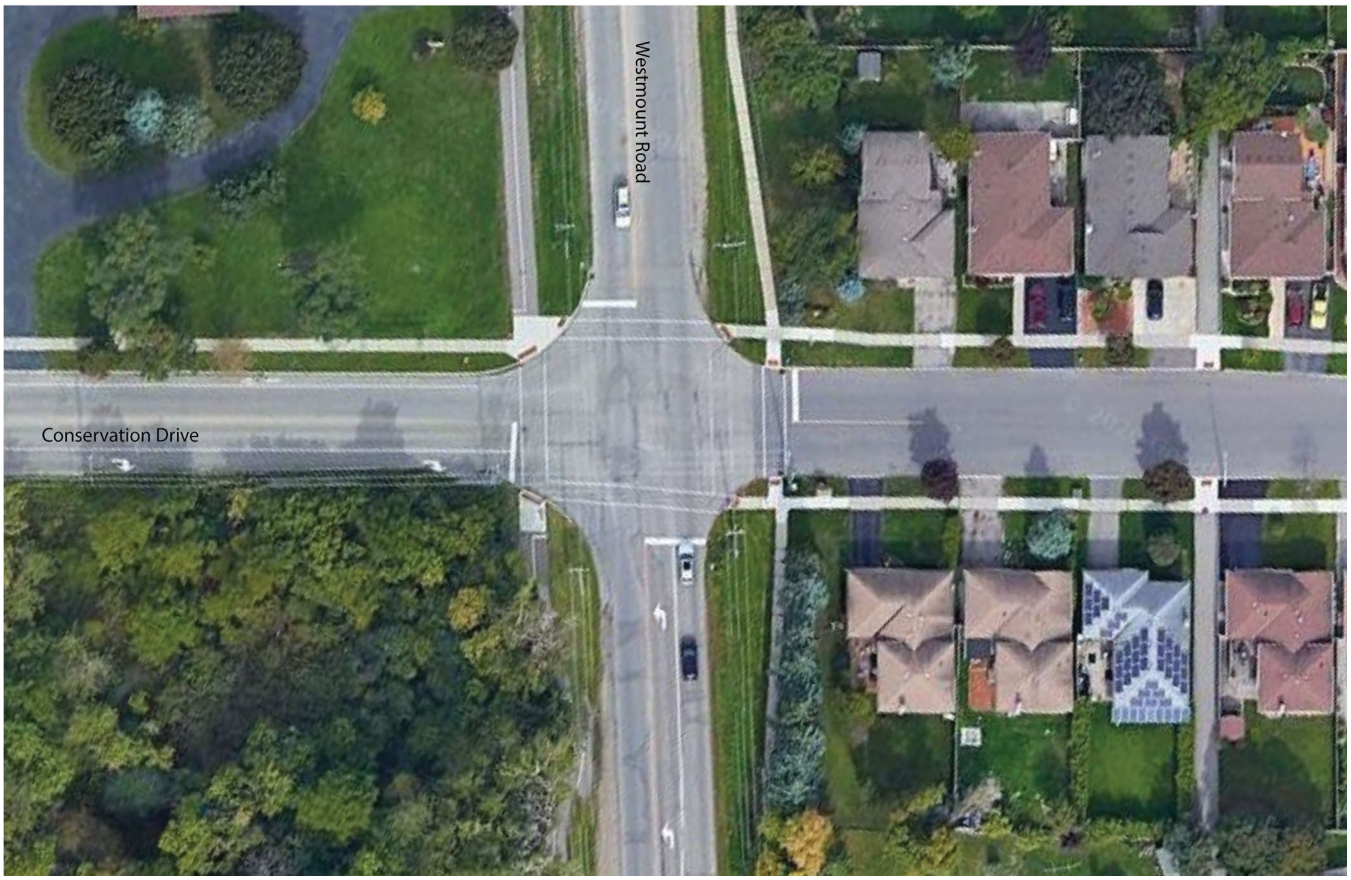


Figure 9. Existing conditions of Conservation and Westmount

The following are design interventions applied to this crossing (shown in Figure 10):

- Protected corners are provided on the NW and SW corners, separating pedestrian, cyclist, and motorist movements through the intersection.
- MUPs are split into sidewalk and cycle track on each approach.
- 10 metre physical radii are provided on the NW and SW corners for vehicles.
- Two-stage pedestrian crossings are provided where pedestrians cross cycle tracks and vehicle lanes.

Further considerations:

- The concept design is compatible with both the existing all-way stop control and a potential future fully signalized control.
- On the eastbound approach, though not shown, an "escape lane" should be provided for the eastbound bicycle lane to allow cyclists to approach the intersection on the MUP rather than mixing with right-turning traffic. An example of an escape lanes is shown in Figure 10.

Figure 10. Example of an escape lane on Ira Needles at Thorndale

Part B – Summary of Countermeasures

The following section summarizes short-term and long-term countermeasures and designs for intersections and crossings that provide benefits for people cycling and walking. The countermeasures are based on the following design guidance documents.

Documents Used to Source Countermeasures

National and Provincial Design Guidance:

- Ontario Traffic Council *Ontario Traffic Manual Book 18: Cycling Facilities* Update (*DRAFT* 2020)
- National Association of City Transportation Officials (NACTO) *Don't Give Up at the Intersection* (2019)
- NACTO *Designing for All Ages & Abilities* (2017)
- Transportation Association of Canada *Geometric Design Guide for Canadian Roads (2017)*
- NACTO *Urban Bikeway Design Guide* (2012)

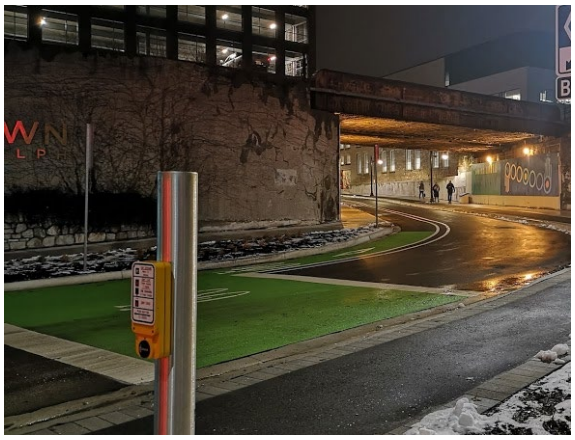
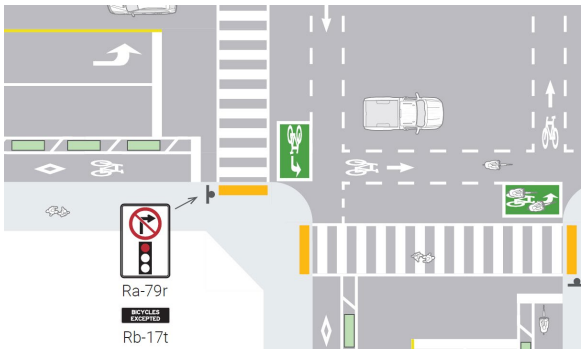
Municipal Design Guidance

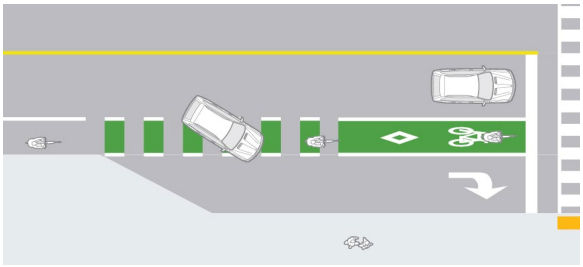
- City of Ottawa Traffic Calming Design Guidelines (2019)
- City of Ottawa Mini-Roundabout Guidelines (2017)
- City of Toronto Curb Radii Guideline (2017)

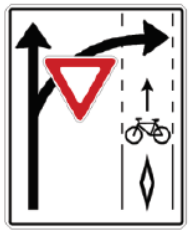
Short-term Countermeasures

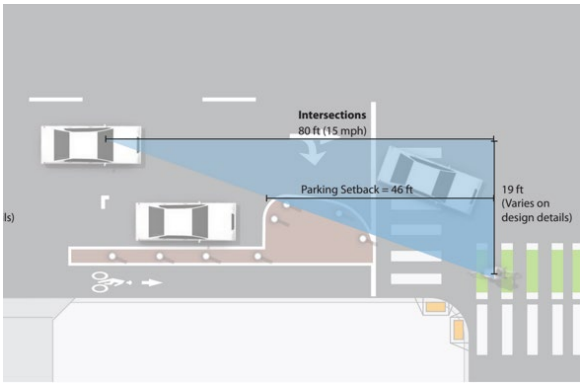
The concept designs shown in Part A are intended to be long-term countermeasures. As an additional tool for use by the City, the following is a list of countermeasures that can generally be implemented at a lower cost and within a shorter timeline. For any of these countermeasures to be applied, additional analysis is required.

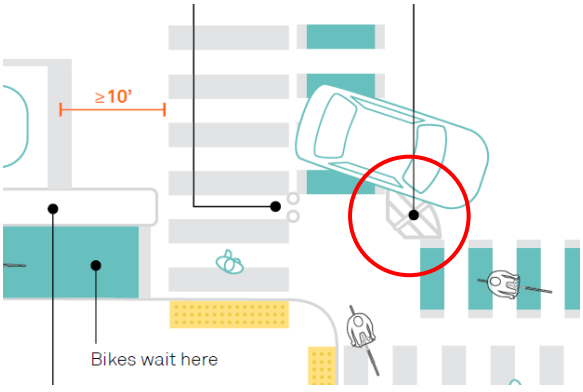
Table 1 – Short-term countermeasures and examples

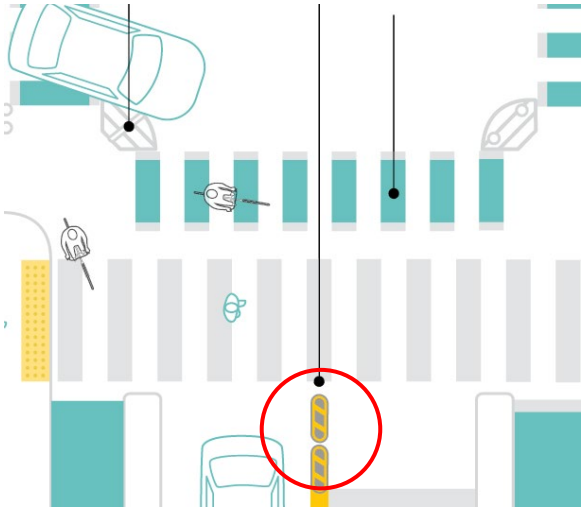
	Countermeasure	Example
1	**Green conflict zone treatment** *Image sources: Alta (Ottawa, ON)*	
2	**Bike box** *Image source: Alta (Guelph, ON)*	
3	**Two-stage left turn box** *Image source: DRAFT OTM Book 18 Update*	

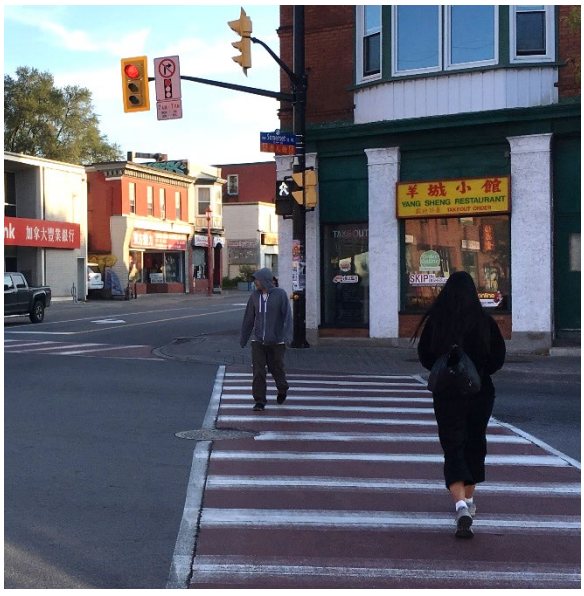
4	**Advanced bicycle stop bar** *Image source: Alta (Ottawa, ON)*	
5	**Floating bicycle lane** *Image source: DRAFT OTM Book 18 Update*	
6	**Shared bicycle lane / turn lane (mixing zone)** *Image source: Alta (Toronto, ON)*	
7	**Strategically placed sharrows or "super sharrows" (as a directional guidance across intersection)** *Image source: Google (Ottawa, ON)*	

8	**On-road messaging** *Image source: City of Ottawa Traffic Calming Design Guidelines (2019)*	
9	**Regulatory or warning signage (examples include):** • Turning Vehicles Yield to Bicycles (TAC RB-37) • Shared Lane Single File (OTM Wc-24) • Bicycle Crossing Ahead (OTM Wc-14) *Image sources: Ontario Traffic Manual*	 RB-37 (TAC) (600 x 750 mm) Wc-24 (OTM) (60 cm x 60 cm) Wc-24t (OTM) (30 cm x 60 cm)
10	**Speed display devices** *Image source: City of Ottawa Traffic Calming Design Guidelines (2019)*	

11	**Parking setbacks** *Image source: Denver Moves Design Guideline (2015)*	
12	**Education (to target a specific behavioural issue)**	
13	**Enforcement (to target a specific behavioural issue)**	
14	**Vertical centerline treatments** *Image source: City of Ottawa Traffic Calming Design Guidelines (2019)*	
15	**Speed cushions and speed humps** *Image source: Alta (Kelowna, BC)*	

16	**Visual lane narrowing** *Image source: City of Ottawa Traffic Calming Design Guidelines (2019)*	
17	**Corner radii reductions and curb extensions (using temporary materials such as paint and/or flex posts)** *Image source: Alta (Portland, OR)*	
18	**Protected bike lanes on approach to intersection (using temporary physical measures such as flex posts or concrete curbs)** *Image source: Alta (Ottawa, ON)*	
19	**Corner wedge & speed bump** *Image source: NACTO Don't Give Up at the Intersection (2019)*	

20	**Centreline hardening (using flex posts or curbs)** *Image source: NACTO Don't Give Up at the Intersection (2019)*	
21	**Setback crossing or protected intersection (using temporary materials)** *Image source: Alta (Oakland, CA)*	
22	**Vehicular directional restrictions (fully or by time-of-day)** *Image source: Alta (Ottawa, ON)*	

23	**Right-turn-on-red restriction (fully or by time-of-day)** *Image source: Ontario Traffic Manual*	 Rb-79R (OTM) (600 x 900 mm)
24	**Traffic diversion and intersection channelizations (using temporary materials)** *Image source: NACTO Urban Bikeway Design Guide*	
25	**Leading pedestrian / bicycle interval** *Image source: Alta (Ottawa, ON)*	

26	**Signal phasing and timing adjustments** *Image source: Alta (Ottawa, ON)*	
27	**Floating transit island (using temporary materials)** *Image source: People for Bikes*	

Long-term Countermeasures

The following list of countermeasures have been considered as options when completing the concept designs for each intersection.

- Overall intersection control
  - Full signalization
  - All-way stop-control
  - Minor leg stop-control
  - Pedestrian crossover (PXO)
  - Intersection pedestrian signal or midblock pedestrian signal (with bicycle signal)
  - Vehicle priority roundabout
  - Bicycle and pedestrian priority roundabout
  - Mini-roundabout
  - Neighbourhood traffic circle
  - Grade separated crossing
- Signal measures
  - Protected left/right turns
  - Advanced detection
  - Bicycle-friendly signal coordination
  - Bicycle-pedestrian scramble
  - Two-stage crossings
- Configuration
  - Vehicle lane reductions / reconfigurations
  - Crossride at one or multiple legs
  - Alternate routing for bicycles
- Horizontal / vertical alignment
  - Setback crossings / protected intersection
  - Relocate floating bicycle lane as setback cycle track crossing
  - Corner radii reductions
  - Truck aprons
  - Curb extensions
  - Centre medians
  - Traffic diversion and channelization
  - Remove right-turn channels or convert to Smart Channels
  - Raised crossings
  - Raised intersection
  - Transit boarding islands / bulb-outs
- Other
  - Streetscaping

16 IMPLEMENTATION COSTS FOR PLANNING CYCLING PROJECTS

Date: April 14, 2020

To: Christopher Hodgson, City of Waterloo

From: Nataliya Pekar, Alta Planning + Design

Cc: Kate Whitfield, Alta Planning + Design

Gene Chartier, Paradigm Transportation Solutions Limited

Re: **Waterloo TMP – Active Transportation – Implementation Costs for Planning Cycling Projects**

Attached: WaterlooTMP_ATImplementationCostsFinal.xlsx

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1 Introduction

As part of the TMP process, a review and update has been undertaken of the 2011 TMP schedule of unit costs for implementing cycling infrastructure. This cover memo provides an introduction and rationale to the facility types, with the final deliverable attached in the form of an excel spreadsheet.

The facility costs were provided for both capital and retrofit projects where relevant. A retrofit project is understood to be a stand-alone initiative, where the cycling project pays for the entirety of the works. Typically, these scenarios are assumed to be implemented where roadway width is available and curb relocation is not necessary to accommodate cycling infrastructure. A capital project is a cycling project that is bundled with major roadway works such as reconstruction, resurfacing, sewer / watermain works, etc., where the cycling facility pays only for associated cost of full depth pavement. It is assumed that a cycling project that requires curb relocation would be bundled with a capital project, where the cycling facility would pay for associated costs of road works and not for costs associated with curb relocation and drainage infrastructure.

In some cases, a cycling project with curb relocation may be undertaken as a retrofit project, where the cycling facility costs includes curb relocation, moving catch-basins, etc. This scenario is similar to a capital project, but adds the cost of curb reconstruction and catch-basin relocation to the cycling project. This scenario is not separately included in the facility types, but can be derived from the unit cost sheet. It is assumed that cycle tracks will always require curb relocation and the facility cost assumes this work is paid for by the cycling project. Finally, projects may also be undertaken within the existing road width but as capital projects bundled with road reconstruction, resurfacing, or underground work to save on mobilization, engineering costs, etc. These savings are realized on a case-by-case basis and are not directly reflected.

Updated facility costs generally represent an increase from the 2011 TMP. While there is limited information on how 2011 TMP costs were obtained, an increase is consistent with inflation and added complexity in cycling facility design (ex. curb relocation).

With the definition of capital and retrofit in mind, the costed facilities and associated assumptions are summarized in **Table 1**.

Table 1: Active Transportation Facilities for Costing

Facility	Project	Assumption
Conventional Bike Lane	Capital	Curbs need to be moved
Conventional Bike Lane	Retrofit	Road space is available and paved
Conventional Buffered Bike Lane	Capital	Curbs need to be moved
Conventional Buffered Bike Lane	Retrofit	Road space is available and paved
Physically Separated Bike Lane	Capital	Curbs need to be moved
Physically Separated Bike Lane	Retrofit	Road space is available and paved
Cycle Tracks	-	Curbs need to be moved
In-boulevard Multi-use Path	-	Existing roadway width remains
Multi-use Trail	-	Off-road in green space
Bicycle greenway	-	Within the existing roadway width
Sidewalk	Retrofit	Dedicated annual budget – includes major works
Sidewalk	Capital	Part of tender road program – includes only associated costs

A unit cost sheet is provided for an exhaustive list of incorporated costs. Several unit costs are provided for reference but are not explicitly costed into the facility. The following items have either been excluded from the facility costs or included as a blanket contingency (ex. pole relocations). They should ultimately be evaluated on a case-by-case basis.

- Pole relocations
- Street furniture
- Bus stop/transit stops
- Property acquisition
- Major roadside drainage works
- Bridges / overpasses
- Railway crossings
- Retaining walls
- Stairways / ramps
- Landscaping and tree removal
- Major intersections
- Taxes and permit fees

Costs are intended for high-level planning purposes. Unit costs are based on sources in southern Ontario. Costing assumes typical grading and environment conditions. Individual assumptions and methodologies are detailed in the deliverable spreadsheet.

Facility Type	Total per Km	Assumption
Conventional Bike Lane - Capital	$ 500,000	1.8 m bike lane, curbs need to be moved, curb relocation paid for by capital project
Conventional Bike Lane - Retrofit	$ 50,000	Road space is available and paved (4 to 3 lane conversion)
Conventional Buffered Bike Lane - Capital	$ 550,000	1.5 + 0.3 m bike lane, curbs need to be moved, curb relocation paid for by capital project
Conventional Buffered Bike Lane - Retrofit	$ 80,000	Road space is available and paved
Physically Separated Bike Lane - Capital	$ 800,000	1.5 + 0.3 m bike lane, curbs need to be moved, curb relocation paid for by capital project
Physically Separated Bike Lane - Retrofit	$ 260,000	Road space is available and paved
Cycle Track	$ 1,350,000	1.8 m wide cycle track, curbs need to be moved, cycle project pays for curb relocation (assumes major utility relocation)
In-boulevard Multi-use Path	$ 470,000	Existing roadway width remains, assumed that 3 m wide MUP is installed in boulevard space (assumes major utility relocation)
Multi-use Trail	$ 650,000	3 m wide MUT, off-road in green space, includes lighting
Bicycle Greenway	$ 90,000	Within the existing roadway width, includes signs and traffic calming
Sidewalk - Capital	$ 320,000	2.0 m wide, part of tender road program, includes only associated costs
Sidewalk - Retrofit	$ 520,000	2.0 m wide, dedicated annual budget

Assumptions

Capital - refers to a bundled project, where the cycling facility cost would only include associated costs, such as new road (granular base, asphalt) for the facility

Retrofit - refers to a project that is stand-alone where the cycling project pays for all costs

No capital or retrofit specified for projects where road works covered by cycling budget irrespective of capital or retrofit, if major road works not associated with project, or if outside of roadway

Each cost assumes both sides with the exception of Multi-use Trail, In-boulevard Multi-use Path, and Sidewalk

Facility terminology is consistent with AT plan

Current data for Waterloo, provided by PM

Facility Type	Total $ per Km (assumes both sides)	Comment
Standard Bike Lane	7,750 - 15,500	Assumes road space is already available and paved, requires bike lane paint only (spacing of symbols and signs every 200m)
Separated Bike Lane (painted buffer)	12,500 - 20,000	Assumes road space is already available and paved, requires bike lane paint only (spacing of symbols and signs every 200m). Paint for hatched areas in buffer in Cold Plastic paint
Separated (raised curb)	66,000 - 140,000	Roll-over curb only
Signed Route	2500	Includes signs and installation (spacing of signs every 200m)
M-U-T Regular	238,000	Excludes curbs or AODA plates
M-U-T Heavy Duty	306,000	Selected for high priority routes that are winter maintained. Excludes curbs or AODA plates
Cycle Track	238,000 - 305,000	Excludes curbs or AODA plates
Sidewalk	176,000 - 248,000	1.8m wide concrete sidewalk at 125mm depth. Excludes cost of AODA plates
Bike lane as part of road widening	188,000 - 195,500	Includes full depth pavement construction 1.8m wide, paint and signs. Excludes curbs
Separated bike lane as part of road widening	254,000 - 335,500	Includes full depth pavement construction 1.8m wide, roll-over curbs, paint and signs. Excludes second barrier curb

City of Waterloo - High Level Cost Estimate AT
Unit Prices and Assumptions

Feature	Unit	Unit Cost	Inflation Adjusted Unit Cost	Notes and Assumptions
Remove and Replace Concrete Curb	m	$ 160	$ 163	
Excavation	m3	$ 40	$ 41	
Clearing and Grubbing	m^2	$ 8	$ 8	
Sod	m2	$ 21	$ 21	Including topsoil and watering
Asphalt Path (incl. clearout, and granular)	m^2	$ 83	$ 84	
Roadway Construction	m^2	$ 90	$ 92	Including granular A & B and asphalt surface
Concrete Sidewalk	m^2	$ 95	$ 97	
Diverter/Mid-block choker	each	$ 18,000	$ 18,360	Cost depends upon size, drainage, and landscaping infrastrucutre. Minimum cost shown for mid-block choker, one corner for bulb-out/curb extension/diverter
Installation of Speed Humps	each	$ 2,500	$ 2,550	
Pavement Marking Removal	m	$ 3	$ 3	
Pavement Marking	m	$ 5	$ 5	
Green Bike Lane Treatment	m^2	$ 60	$ 61	CycleGrip Max thermoplast
Bicycle Stencil Pavement Marking	each	$ 150	$ 153	
Bicycle Signal Head	each	$ 3,800	$ 3,876	Mounted to existing signal pole
Signage Installation - Trail	each	$ 75	$ 77	
Signage Installation - Road	each	$ 300	$ 306	
Catch Basin Relocation + Lead	each	$ 2,800	$ 2,856	
Adjust Manhole Frame and Cover	each	$ 650	$ 663	
Hydro Pole Relocation - Small with Wooden Post	each	$ 10,000	$ 10,200	The $10,000 to relocate wooden hydro poles is the minimum price. If there are any other utilities on the pole the price will increase
Hydro Pole Relocation - Large with Concrete Pole	each	$ 15,000	$ 15,300	
Hydro Box Relocation	each	$ 20,000	$ 20,400	
Fire Hydrant Relocation	each	$ 5,500	$ 5,610	
Streetlight Relocation	each	$ 7,500	$ 7,650	
Replacement of Trees	each	$ 500	$ 510	Can cost up to 6000. Includes planting a single tree for every tree removed regardless of the size of tree removed
Pre-cast Concrete Curbs & Flexible Delineator Posts	per m	$ 75	$ 77	
Pathway Lighting	m	$ 160	$ 163	Includes cabling, connection to power supply, transformers, and fixtures
			Contingency (10%)	
			Engineering (10%)	Includes engineering design
			Contract Administration (5%)	
			Traffic Control (10%)	
			Utilities (5-20%)	20% applied where project requires curb relocation, otherwise 5% is applied for minor utility works and where major utility works are covered in overal project (capital)
			Internal Costs (4%)	

Adjustment for Inflation	
Input Year	2020
Applied Factor	**1.02**

Assume average annual inflation of 2% applied to all costs, original costs at year 2019

City of Waterloo - High Level Cost Estimate Active Transportation
Unit Prices and Assumptions
Facility: Conventional Bike Lane - Capital
Includes: 1.8 m bike lane, pavement markings, signage, asphalt for bike lane portion of roadway

Feature	Unit	Estimated Quantity	Unit Cost	Total Cost	Notes
Remove and Replace Concrete Curb	m		$ 163	$ -	
Excavation	m3		$ 41	$ -	
Clearing and Grubbing	m2		$ 8	$ -	
Sod	m2		$ 21	$ -	
Asphalt Path (incl. clearout, and granular)	m2		$ 84	$ -	
Roadway Construction	m2	3600	$ 92	$ 330,480	Including granular A & B and asphalt surface
Concrete Sidewalk	m2		$ 97	$ -	
Diverter/Mid-block choker	each		$ 18,360	$ -	
Installation of Speed Humps	each		$ 2,550	$ -	
Pavement Marking Removal	m		$ 3	$ -	
Pavement Marking	m	2000	$ 5	$ 10,200	Bike lane line on both sides
Green Bike Lane Treatment	m2		$ 61	$ -	
Bicycle Stencil Pavement Marking	each	10	$ 153	$ 1,530	Every 200 m on both sides
Bicycle Signal Head	each		$ 3,876	$ -	
Signage Installation - Trail	each		$ 77	$ -	
Signage Installation - Road	each	10	$ 306	$ 3,060	Bicycle lane signs, every 200 m, both sides
Catch Basin Relocation + Lead	each		$ 2,856	$ -	
Adjust Manhole Frame and Cover	each		$ 663	$ -	
Hydro Pole Relocation - Small with Wooden Post	each		$ 10,200	$ -	
Hydro Pole Relocation - Large with Concrete Pole	each		$ 15,300	$ -	
Hydro Box Relocation	each		$ 20,400	$ -	
Fire Hydrant Relocation	each		$ 5,610	$ -	
Streetlight Relocation	each		$ 7,650	$ -	
Replacement of Trees	each		$ 510	$ -	
Pre-cast Concrete Curbs & Flexible Delineator Posts	per m		$ 77	$ -	
Pathway Lighting	m		$ 163	$ -	
			Sub-total	$ 345,270	
			Contingency (10%)	$ 34,527	
			Engineering (10%)	$ 34,527	Includes engineering design
			Contract Administration (5%)	$ 17,264	
			Traffic Control (10%)	$ 34,527	
			Utilities (5%)	$ 17,264	Major utilities included in overall project cost
			Internal Costs (4%)	$ 13,811	
			Total Cost (rounded per km)	**$ 500,000**	

EXCLUDES

Curb, gutter, excavation and grading, and catch basin construction included in overall project cost
Intersection works

City of Waterloo - High Level Cost Estimate Active Transportation
Unit Prices and Assumptions
Facility: Conventional Bike Lane - Retrofit
Includes: Pavement markings and signage

Feature	Unit	Estimated Quantity	Unit Cost	Total Cost	Notes
Remove and Replace Concrete Curb	m		$ 163	$ -	
Excavation	m3		$ 41	$ -	
Clearing and Grubbing	m2		$ 8	$ -	
Sod	m2		$ 21	$ -	
Asphalt Path (incl. clearout, and granular)	m2		$ 84	$ -	
Roadway Construction	m2		$ 92	$ -	
Concrete Sidewalk	m2		$ 97	$ -	
Diverter/Mid-block choker	each		$ 18,360	$ -	
Installation of Speed Humps	each		$ 2,550	$ -	
Pavement Marking Removal	m	3000	$ 3	$ 9,180	Assume re-stripping from 4 to 3 lane roadway - removal on both sides
Pavement Marking	m	4000	$ 5	$ 20,400	Bike lane lines and vehicle travel lane lines
Green Bike Lane Treatment	m2		$ 61	$ -	
Bicycle Stencil Pavement Marking	each	10	$ 153	$ 1,530	Every 200 m on both sides
Bicycle Signal Head	each		$ 3,876	$ -	
Signage Installation - Trail	each		$ 77	$ -	
Signage Installation - Road	each	10	$ 306	$ 3,060	Bicycle lane signs, every 200 m, both sides
Catch Basin Relocation + Lead	each		$ 2,856	$ -	
Adjust Manhole Frame and Cover	each		$ 663	$ -	
Hydro Pole Relocation - Small with Wooden Post	each		$ 10,200	$ -	
Hydro Pole Relocation - Large with Concrete Pole	each		$ 15,300	$ -	
Hydro Box Relocation	each		$ 20,400	$ -	
Fire Hydrant Relocation	each		$ 5,610	$ -	
Streetlight Relocation	each		$ 7,650	$ -	
Replacement of Trees	each		$ 510	$ -	
Pre-cast Concrete Curbs & Flexible Delineator Posts	per m		$ 77	$ -	
Pathway Lighting	m		$ 163	$ -	
			Sub-total	$ 34,170	
			Contingency (10%)	$ 3,417	
			Engineering (10%)	$ 3,417	Includes engineering design
			Contract Administration (5%)	$ 1,709	
			Traffic Control (10%)	$ 3,417	
			Utilities (5%)	$ 1,709	
			Internal Costs (4%)	$ 1,367	
			Total Cost (rounded per km)	**$ 50,000**	

EXCLUDES

No roadway construction, only line-painting and signage is included
Intersection works

City of Waterloo - High Level Cost Estimate Active Transportation
Unit Prices and Assumptions
Facility: Conventional Buffered Bike Lane - Capital
Includes: Pavement markings, signage, and asphalt for bike lane portion of roadway

Feature	Unit	Estimated Quantity	Unit Cost	Total Cost	Notes
Remove and Replace Concrete Curb	m		$ 163	$ -	
Excavation	m3		$ 41	$ -	
Clearing and Grubbing	m2		$ 8	$ -	
Sod	m2		$ 21	$ -	
Asphalt Path (incl. clearout, and granular)	m2		$ 84	$ -	
Roadway Construction	m2	3600	$ 92	$ 330,480	Including granular A & B and asphalt surface
Concrete Sidewalk	m2		$ 97	$ -	
Diverter/Mid-block choker	each		$ 18,360	$ -	
Installation of Speed Humps	each		$ 2,550	$ -	
Pavement Marking Removal	m	3000	$ 3	$ 9,180	Assume re-stripping from 4 to 3 lane roadway - removal on both sides
Pavement Marking	m	8000	$ 5	$ 40,800	Bike lane lines and vehicle travel lane lines, assume 3 m per m in buffer
Green Bike Lane Treatment	m2		$ 61	$ -	
Bicycle Stencil Pavement Marking	each	10	$ 153	$ 1,530	Every 200 m on both sides
Bicycle Signal Head	each		$ 3,876	$ -	
Signage Installation - Trail	each		$ 77	$ -	
Signage Installation - Road	each	10	$ 306	$ 3,060	Bicycle lane signs, every 200 m, both sides
Catch Basin Relocation + Lead	each		$ 2,856	$ -	
Adjust Manhole Frame and Cover	each		$ 663	$ -	
Hydro Pole Relocation - Small with Wooden Post	each		$ 10,200	$ -	
Hydro Pole Relocation - Large with Concrete Pole	each		$ 15,300	$ -	
Hydro Box Relocation	each		$ 20,400	$ -	
Fire Hydrant Relocation	each		$ 5,610	$ -	
Streetlight Relocation	each		$ 7,650	$ -	
Replacement of Trees	each		$ 510	$ -	
Pre-cast Concrete Curbs & Flexible Delineator Posts	per m		$ 77	$ -	
Pathway Lighting	m		$ 163	$ -	
			Sub-total	$ 385,050	
			Contingency (10%)	$ 38,505	
			Engineering (10%)	$ 38,505	Includes engineering design
			Contract Administration (5%)	$ 19,253	
			Traffic Control (10%)	$ 38,505	
			Utilities (5%)	$ 19,253	Major utilities included in overall project cost
			Internal Costs (4%)	$ 15,402	
			Total Cost (rounded per km)	**$ 550,000**	

EXCLUDES

Curb, gutter, excavation and grading, and catch basin construction included in overall project cost

City of Waterloo - High Level Cost Estimate Active Transportation
Unit Prices and Assumptions
Facility: Conventional Buffered Bike Lane - Retrofit
Includes: Pavement markings and signage

Feature	Unit	Estimated Quantity	Unit Cost	Total Cost	Notes
Remove and Replace Concrete Curb	m		$ 163	$ -	
Excavation	m3		$ 41	$ -	
Clearing and Grubbing	m2		$ 8	$ -	
Sod	m2		$ 21	$ -	
Asphalt Path (incl. clearout, and granular)	m2		$ 84	$ -	
Roadway Construction	m2		$ 92	$ -	
Concrete Sidewalk	m2		$ 97	$ -	
Diverter/Mid-block choker	each		$ 18,360	$ -	
Installation of Speed Humps	each		$ 2,550	$ -	
Pavement Marking Removal	m	3000	$ 3	$ 9,180	Assume re-stripping from 4 to 3 lane roadway - removal on both sides
Pavement Marking	m	8000	$ 5	$ 40,800	Bike lane lines and vehicle travel lane lines, assume 3 m per m in buffer
Green Bike Lane Treatment	m2		$ 61	$ -	
Bicycle Stencil Pavement Marking	each	10	$ 153	$ 1,530	Every 200 m on both sides
Bicycle Signal Head	each		$ 3,876	$ -	
Signage Installation - Trail	each		$ 77	$ -	
Signage Installation - Road	each	10	$ 306	$ 3,060	Bicycle lane signs, every 200 m, both sides
Catch Basin Relocation + Lead	each		$ 2,856	$ -	
Adjust Manhole Frame and Cover	each		$ 663	$ -	
Hydro Pole Relocation - Small with Wooden Post	each		$ 10,200	$ -	
Hydro Pole Relocation - Large with Concrete Pole	each		$ 15,300	$ -	
Hydro Box Relocation	each		$ 20,400	$ -	
Fire Hydrant Relocation	each		$ 5,610	$ -	
Streetlight Relocation	each		$ 7,650	$ -	
Replacement of Trees	each		$ 510	$ -	
Pre-cast Concrete Curbs & Flexible Delineator Posts	per m		$ 77	$ -	
Pathway Lighting	m		$ 163	$ -	
			Sub-total	$ 54,570	
			Contingency (10%)	$ 5,457	
			Engineering (10%)	$ 5,457	Includes engineering design
			Contract Administration (5%)	$ 2,729	
			Traffic Control (10%)	$ 5,457	
			Utilities (5%)	$ 2,729	
			Internal Costs (4%)	$ 2,183	
			Total Cost (rounded per km)	**$ 80,000**	

EXCLUDES

No roadway construction, only line-painting and signage is included
Intersection works

City of Waterloo - High Level Cost Estimate Active Transportation
Unit Prices and Assumptions
Facility: Physically Separated - Capital
Includes: Pavement markings, signage, and asphalt for bike lane portion of roadway

Feature	Unit	Estimated Quantity	Unit Cost	Total Cost	Notes
Remove and Replace Concrete Curb	m		$ 163	$ -	
Excavation	m3		$ 41	$ -	
Clearing and Grubbing	m2		$ 8	$ -	
Sod	m2		$ 21	$ -	
Asphalt Path (incl. clearout, and granular)	m2		$ 84	$ -	
Roadway Construction	m2	3600	$ 92	$ 330,480	Including granular A & B and asphalt surface
Concrete Sidewalk	m2		$ 97	$ -	
Diverter/Mid-block choker	each		$ 18,360	$ -	
Installation of Speed Humps	each		$ 2,550	$ -	
Pavement Marking Removal	m		$ 3	$ -	
Pavement Marking	m	6000	$ 5	$ 30,600	Buffered bike lane line assume 3 m per m in buffer
Green Bike Lane Treatment	m2	320.00	$ 61	$ 19,584	Assume intersection every 250 m, 20 m x 2 m wide crossride per direction
Bicycle Stencil Pavement Marking	each	10.00	$ 153	$ 1,530	Every 200 m on both sides
Bicycle Signal Head	each	16.00	$ 3,876	$ 62,016	Bike signal head - 2 per crossride per direction, assumed intersection every 250 m
Signage Installation - Trail	each		$ 77	$ -	
Signage Installation - Road	each	20.00	$ 306	$ 6,120	Signage every 100 m due to assumed high driveway density
Catch Basin Relocation + Lead	each		$ 2,856	$ -	
Adjust Manhole Frame and Cover	each		$ 663	$ -	
Hydro Pole Relocation - Small with Wooden Post	each		$ 10,200	$ -	
Hydro Pole Relocation - Large with Concrete Pole	each		$ 15,300	$ -	
Hydro Box Relocation	each		$ 20,400	$ -	
Fire Hydrant Relocation	each		$ 5,610	$ -	
Streetlight Relocation	each		$ 7,650	$ -	
Replacement of Trees	each		$ 510	$ -	
Pre-cast Concrete Curbs & Flexible Delineator Posts	per m	1400.00	$ 77	$ 107,100	Assume 30% of length will have no separation due to breaks for driveways and minor roadways
Pathway Lighting	m		$ 163	$ -	
			Sub-total	$ 557,430.00	
			Contingency (10%)	$ 55,743.0	
			Engineering (10%)	$ 55,743.0	Includes engineering design
			Contract Administration (5%)	$ 27,871.50	
			Traffic Control (10%)	$ 55,743.0	
			Utilities (5%)	$ 27,871.50	Major utilities included in overall project cost
			Internal Costs (4%)	$ 22,297	
			Total Cost (rounded per km)	**$ 800,000**	

EXCLUDES

Curb, gutter, excavation and grading, and catch basin construction included in overall project cost
Intersection works

City of Waterloo - High Level Cost Estimate Active Transportation
Unit Prices and Assumptions
Facility: Physically Separated - Retrofit
Includes: Pavement markings and signage

Feature	Unit	Estimated Quantity	Unit Cost	Total Cost	Notes
Remove and Replace Concrete Curb	m		$ 163	$ -	
Excavation	m3		$ 41	$ -	
Clearing and Grubbing	m2		$ 8	$ -	
Sod	m2		$ 21	$ -	
Asphalt Path (incl. clearout, and granular)	m2		$ 84	$ -	
Roadway Construction	m2		$ 92	$ -	
Concrete Sidewalk	m2		$ 97	$ -	
Diverter/Mid-block choker	each		$ 18,360	$ -	
Installation of Speed Humps	each		$ 2,550	$ -	
Pavement Marking Removal	m	3000	$ 3	$ 9,180	Assume re-stripping from 4 to 3 lane roadway - removal on both sides
Pavement Marking	m	6000	$ 5	$ 30,600	Buffered bike lane line assume 3 m per m in buffer
Green Bike Lane Treatment	m2	320.00	$ 61	$ 19,584	Assume intersection every 250 m, 20 m x 2 m wide crossride per direction
Bicycle Stencil Pavement Marking	each	10.00	$ 153	$ 1,530	Every 200 m on both sides
Bicycle Signal Head	each	16.00	$ 3,800	$ 60,800	Bike signal head - 2 per crossride per direction, assumed intersection every 250 m
Signage Installation - Trail	each		$ 77	$ -	
Signage Installation - Road	each	20.00	$ 306	$ 6,120	Signage every 100 m due to assumed high driveway density
Catch Basin Relocation + Lead	each		$ 2,856	$ -	
Adjust Manhole Frame and Cover	each		$ 663	$ -	
Hydro Pole Relocation - Small with Wooden Post	each		$ 10,200	$ -	
Hydro Pole Relocation - Large with Concrete Pole	each		$ 15,300	$ -	
Hydro Box Relocation	each		$ 20,400	$ -	
Fire Hydrant Relocation	each		$ 5,610	$ -	
Streetlight Relocation	each		$ 7,650	$ -	
Replacement of Trees	each		$ 510	$ -	
Pre-cast Concrete Curbs & Flexible Delineator Posts	per m	700.00	$ 77	$ 53,550	Assume 30% of length will have no separation due to breaks for driveways and minor roadways
Pathway Lighting	m		$ 163	$ -	
			Sub-total	$ 181,364.00	
			Contingency (10%)	$ 18,136.4	
			Engineering (10%)	$ 18,136.4	Includes engineering design
			Contract Administration (5%)	$ 9,068.20	
			Traffic Control (10%)	$ 18,136.4	
			Utilities (5%)	$ 9,068.20	
			Internal Costs (4%)	$ 7,255	
			Total Cost (rounded per km)	**$ 260,000**	

EXCLUDES

No roadway construction, only line-painting and signage is included
Intersection works

City of Waterloo - High Level Cost Estimate Active Transportation
Unit Prices and Assumptions
Facility: Cycle Track
Includes: Curb reconstruction, 1.8 m cycle track, bicycle signals, pavement markings, signs

Feature	Unit	Estimated Quantity	Unit Cost	Total Cost	Notes
Remove and Replace Concrete Curb	m	2000	$ 163	$ 326,400	
Excavation	m3	1080	$ 41	$ 44,064	Assume full width of cycle track, 300 mm depth
Clearing and Grubbing	m2		$ 8	$ -	
Sod	m2		$ 21	$ -	
Asphalt Path (incl. clearout, and granular)	m2	3600	$ 84	$ 302,940	1.8 m width of cycle track
Roadway Construction	m2		$ 92	$ -	
Concrete Sidewalk	m2		$ 97	$ -	
Diverter/Mid-block choker	each		$ 18,360	$ -	
Installation of Speed Humps	each		$ 2,550	$ -	
Pavement Marking Removal	m	3000	$ 3	$ 9,180	Assume re-striping of roadway (4 to 3 lanes)
Pavement Marking	m	2000	$ 5	$ 10,200	
Green Bike Lane Treatment	m2	320	$ 61	$ 19,584	Assume intersection every 250 m, 20 m x 2 m wide crossride per direction
Bicycle Stencil Pavement Marking	each	10	$ 153	$ 1,530	Every 200 m on both sides
Bicycle Signal Head	each	16	$ 3,800	$ 60,800	Bike signal head - 2 per crossride per direction, assumed intersection every 250 m
Signage Installation - Trail	each		$ 77	$ -	
Signage Installation - Road	each	20	$ 306	$ 6,120	Signage every 100 m due to assumed high driveway density
Catch Basin Relocation + Lead	each	20	$ 2,856	$ 57,120	Assume catch basin relocation + lead every 100 m on both sides
Adjust Manhole Frame and Cover	each	16	$ 663	$ 10,608	Assume manhole every 125 m on both sides
Hydro Pole Relocation - Small with Wooden Post	each		$ 10,200	$ -	
Hydro Pole Relocation - Large with Concrete Pole	each		$ 15,300	$ -	
Hydro Box Relocation	each		$ 20,400	$ -	
Fire Hydrant Relocation	each		$ 5,610	$ -	
Streetlight Relocation	each		$ 7,650	$ -	
Replacement of Trees	each		$ 510	$ -	
Pre-cast Concrete Curbs & Flexible Delineator Posts	per m		$ 77	$ -	
Pathway Lighting	m		$ 163	$ -	
			Sub-total	$ 848,546	
			Contingency (10%)	$ 84,855	
			Engineering (10%)	$ 84,855	Includes engineering design
			Contract Administration (5%)	$ 42,427	
			Traffic Control (10%)	$ 84,855	
			Utilities (20%)	$ 169,709	Major utility relocation
			Internal Costs (4%)	$ 33,942	
			Total Cost (rounded per km)	**$ 1,350,000**	

EXCLUDES
Major intersection works

City of Waterloo - High Level Cost Estimate Active Transportation
Unit Prices and Assumptions
Facility: In-Boulevard Multi-use Path
Includes: 3.0 m asphalt path, pavement markings, signage

Feature	Unit	Estimated Quantity	Unit Cost	Total Cost	Notes
Remove and Replace Concrete Curb	m		$ 163	$ -	
Excavation	m3	900	$ 41	$ 36,720	Assume 300 mm depth by 3 m width
Clearing and Grubbing	m2		$ 8	$ -	
Sod	m2		$ 21	$ -	
Asphalt Path (incl. clearout, and granular)	m2	3000	$ 84	$ 252,450	3.0 m wide MUP
Roadway Construction	m2		$ 92	$ -	
Concrete Sidewalk	m2		$ 97	$ -	
Diverter/Mid-block choker	each		$ 18,360	$ -	
Installation of Speed Humps	each		$ 2,550	$ -	
Pavement Marking Removal	m		$ 3	$ -	
Pavement Marking	m	1000	$ 5	$ 5,100	Solid yellow centre lane line for full length
Green Bike Lane Treatment	m2		$ 61	$ -	
Bicycle Stencil Pavement Marking	each	5	$ 153	$ 765	MUP pavement markings every 200 m
Bicycle Signal Head	each		$ 3,876	$ -	
Signage Installation - Trail	each	10	$ 77	$ 765	Shared use pathway signs, every 200m
Signage Installation - Road	each		$ 306	$ -	
Catch Basin Relocation + Lead	each		$ 2,856	$ -	
Adjust Manhole Frame and Cover	each		$ 663	$ -	
Hydro Pole Relocation - Small with Wooden Post	each		$ 10,200	$ -	
Hydro Pole Relocation - Large with Concrete Pole	each		$ 15,300	$ -	
Hydro Box Relocation	each		$ 20,400	$ -	
Fire Hydrant Relocation	each		$ 5,610	$ -	
Streetlight Relocation	each		$ 7,650	$ -	
Replacement of Trees	each		$ 510	$ -	
Pre-cast Concrete Curbs & Flexible Delineator Posts	per m		$ 77	$ -	
Pathway Lighting	m		$ 163	$ -	
			Sub-total	$ 295,800	
			Contingency (10%)	$ 29,580	
			Engineering (10%)	$ 29,580	Includes engineering design
			Contract Administration (5%)	$ 14,790	
			Traffic Control (10%)	$ 29,580	
			Utilities (20%)	$ 59,160	Major utility relocation
			Internal Costs (4%)	$ 11,832	
			Total Cost (rounded per km)	**$ 470,000**	

EXCLUDES
Curb reconstruction, roadway widening

City of Waterloo - High Level Cost Estimate Active Transportation
Unit Prices and Assumptions
Facility: Multi-use trail
Includes: 3.0 m asphalt path, pavement markings, signage, and lighting

Feature	Unit	Estimated Quantity	Unit Cost	Total Cost	Notes
Remove and Replace Concrete Curb	m		$ 163	$ -	
Excavation	m3	1500	$ 41	$ 61,200	Assume 300 mm depth by 5 m width
Clearing and Grubbing	m2		$ 8	$ -	
Sod	m2		$ 21	$ -	
Asphalt Path (incl. clearout, and granular)	m2	3000	$ 84	$ 252,450	3.0 m wide MUP
Roadway Construction	m2		$ 92	$ -	
Concrete Sidewalk	m2		$ 97	$ -	
Diverter/Mid-block choker	each		$ 18,360	$ -	
Installation of Speed Humps	each		$ 2,550	$ -	
Pavement Marking Removal	m		$ 3	$ -	
Pavement Marking	m	1000	$ 5	$ 5,100	Solid yellow centre lane line for full length
Green Bike Lane Treatment	m2		$ 61	$ -	
Bicycle Stencil Pavement Marking	each		$ 153	$ -	
Bicycle Signal Head	each		$ 3,876	$ -	
Signage Installation - Trail	each	10	$ 77	$ 765	Shared use pathway signs, every 200m
Signage Installation - Road	each		$ 306	$ -	
Catch Basin Relocation + Lead	each		$ 2,856	$ -	
Adjust Manhole Frame and Cover	each		$ 663	$ -	
Hydro Pole Relocation - Small with Wooden Post	each		$ 10,200	$ -	
Hydro Pole Relocation - Large with Concrete Pole	each		$ 15,300	$ -	
Hydro Box Relocation	each		$ 20,400	$ -	
Fire Hydrant Relocation	each		$ 5,610	$ -	
Streetlight Relocation	each		$ 7,650	$ -	
Replacement of Trees	each		$ 510	$ -	
Pre-cast Concrete Curbs & Flexible Delineator Posts	per m		$ 77	$ -	
Pathway Lighting	m	1000	$ 163	$ 163,200	Includes cabling, connection to power supply, transformers, and fixtures
			Sub-total	$ 482,715	
			Contingency (10%)	$ 48,272	
			Engineering (10%)	$ 4,827	Includes engineering design
			Contract Administration (5%)	$ 24,136	
			Traffic Control (10%)	$ 48,272	
			Utilities (5%)	$ 24,136	
			Internal Costs (4%)	$ 19,309	
			Total Cost (rounded per km)	**$ 650,000**	

EXCLUDES

Roadway crossings (if any)
Access management measures (ex. bollards)

City of Waterloo - High Level Cost Estimate Active Transportation
Unit Prices and Assumptions
Facility: Bicycle Greenway
Includes: Bike route signage, sharrow pavement markings, traffic calming elements

Feature	Unit	Estimated Quantity	Unit Cost	Total Cost	Notes
Remove and Replace Concrete Curb	m		$ 163	$ -	
Excavation	m3		$ 41	$ -	
Clearing and Grubbing	m2		$ 8	$ -	
Sod	m2		$ 21	$ -	
Asphalt Path (incl. clearout, and granular)	m2		$ 84	$ -	
Roadway Construction	m2		$ 92	$ -	
Concrete Sidewalk	m2		$ 97	$ -	
Diverter/Mid-block choker	each	2	$ 18,360	$ 36,720	Cost depends upon size, drainage, and landscaping infrastrucutre. Minimum cost shown for mid-block choker, one corner for bulb-out/curb extension/diverter
Installation of Speed Humps	each	7	$ 2,550	$ 17,000	Provide every 150m to ensure 40km/h compliance
Pavement Marking Removal	m		$ 3	$ -	
Pavement Marking	m		$ 5	$ -	
Green Bike Lane Treatment	m2		$ 61	$ -	
Bicycle Stencil Pavement Marking	each	27	$ 153	$ 4,080	Sharrows installed every 75m (on each side of road)
Bicycle Signal Head	each		$ 3,876	$ -	
Signage Installation - Trail	each		$ 77	$ -	
Signage Installation - Road	each	5	$ 306	$ 1,530	"Bike Route" sign every 400m (on each side of road)
Catch Basin Relocation + Lead	each		$ 2,856	$ -	
Adjust Manhole Frame and Cover	each		$ 663	$ -	
Hydro Pole Relocation - Small with Wooden Post	each		$ 10,200	$ -	
Hydro Pole Relocation - Large with Concrete Pole	each		$ 15,300	$ -	
Hydro Box Relocation	each		$ 20,400	$ -	
Fire Hydrant Relocation	each		$ 5,610	$ -	
Streetlight Relocation	each		$ 7,650	$ -	
Replacement of Trees	each		$ 510	$ -	
Pre-cast Concrete Curbs & Flexible Delineator Posts	per m		$ 77	$ -	
Pathway Lighting	m		$ 163	$ -	
			Sub-total	$ 59,330.00	
			Contingency (10%)	$ 5,933.0	
			Engineering (10%)	$ 5,933.0	Includes engineering design
			Contract Administration (5%)	$ 2,966.50	
			Traffic Control (10%)	$ 5,933.0	
			Utilities (5%)	$ 2,966.50	
			Internal Costs (4%)	$ 2,373	
			Total Cost (rounded per km)	**$ 90,000**	

EXCLUDES
Roadway re-stripping

City of Waterloo - High Level Cost Estimate Active Transportation
Unit Prices and Assumptions
Facility: Sidewalk - Capital
Includes: Excavation and concrete sidewalk

Feature	Unit	Estimated Quantity	Unit Cost	Total Cost	Notes
Remove and Replace Concrete Curb	m		$ 163	$ -	
Excavation	m3	300	$ 41	$ 12,240	Assumes 150 mm depth
Clearing and Grubbing	m2	2000	$ 8	$ 16,320	
Sod	m2		$ 21	$ -	
Asphalt Path (incl. clearout, and granular)	m2		$ 84	$ -	
Roadway Construction	m2		$ 92	$ -	
Concrete Sidewalk	m2	2000	$ 97	$ 193,800	Assumes 2.0 m wide
Diverter/Mid-block choker	each		$ 18,360	$ -	
Installation of Speed Humps	each		$ 2,550	$ -	
Pavement Marking Removal	m		$ 3	$ -	
Pavement Marking	m		$ 5	$ -	
Green Bike Lane Treatment	m2		$ 61	$ -	
Bicycle Stencil Pavement Marking	each		$ 153	$ -	
Bicycle Signal Head	each		$ 3,876	$ -	
Signage Installation - Trail	each		$ 77	$ -	
Signage Installation - Road	each		$ 306	$ -	
Catch Basin Relocation + Lead	each		$ 2,856	$ -	
Adjust Manhole Frame and Cover	each		$ 663	$ -	
Hydro Pole Relocation - Small with Wooden Post	each		$ 10,200	$ -	
Hydro Pole Relocation - Large with Concrete Pole	each		$ 15,300	$ -	
Hydro Box Relocation	each		$ 20,400	$ -	
Fire Hydrant Relocation	each		$ 5,610	$ -	
Streetlight Relocation	each		$ 7,650	$ -	
Replacement of Trees	each		$ 510	$ -	
Pre-cast Concrete Curbs & Flexible Delineator Posts	per m		$ 77	$ -	
Pathway Lighting	m		$ 163	$ -	
			Sub-total	$ 222,360.0	
			Contingency (10%)	$ 22,236.0	
			Engineering (10%)	$ 22,236.0	Includes engineering design
			Contract Administration (5%)	$ 11,118.0	
			Traffic Control (10%)	$ 22,236.0	
			Utilities (5%)	$ 11,118.0	
			Internal Costs (4%)	$ 8,894.4	
			Total Cost (rounded per km)	**$ 320,000.0**	

EXCLUDES
Drainage works

City of Waterloo - High Level Cost Estimate Active Transportation
Unit Prices and Assumptions
Facility: Sidewalk - Retrofit
Includes: Excavation and concrete sidewalk

Feature	Unit	Estimated Quantity	Unit Cost	Total Cost	Notes
Remove and Replace Concrete Curb	m	1000	$ 163	$ 163,200	
Excavation	m3	300	$ 41	$ 12,240	Assumes 150 mm depth
Clearing and Grubbing	m2	2000	$ 8	$ 16,320	
Sod	m2		$ 21	$ -	
Asphalt Path (incl. clearout, and granular)	m2		$ 84	$ -	
Roadway Construction	m2		$ 92	$ -	
Concrete Sidewalk	m2	2000	$ 97	$ 193,800	Assumes 2.0 m wide
Diverter/Mid-block choker	each		$ 18,360	$ -	
Installation of Speed Humps	each		$ 2,550	$ -	
Pavement Marking Removal	m		$ 3	$ -	
Pavement Marking	m		$ 5	$ -	
Green Bike Lane Treatment	m2		$ 61	$ -	
Bicycle Stencil Pavement Marking	each		$ 153	$ -	
Bicycle Signal Head	each		$ 3,876	$ -	
Signage Installation - Trail	each		$ 77	$ -	
Signage Installation - Road	each		$ 306	$ -	
Catch Basin Relocation + Lead	each		$ 2,856	$ -	
Adjust Manhole Frame and Cover	each		$ 663	$ -	
Hydro Pole Relocation - Small with Wooden Post	each		$ 10,200	$ -	
Hydro Pole Relocation - Large with Concrete Pole	each		$ 15,300	$ -	
Hydro Box Relocation	each		$ 20,400	$ -	
Fire Hydrant Relocation	each		$ 5,610	$ -	
Streetlight Relocation	each		$ 7,650	$ -	
Replacement of Trees	each		$ 510	$ -	
Pre-cast Concrete Curbs & Flexible Delineator Posts	per m		$ 77	$ -	
Pathway Lighting	m		$ 163	$ -	
			Sub-total	$ 385,560.00	
			Contingency (10%)	$ 38,556.0	
			Engineering (10%)	$ 3,855.6	Includes engineering design
			Contract Administration (5%)	$ 19,278.00	
			Traffic Control (10%)	$ 38,556.0	
			Utilities (5%)	$ 19,278.00	
			Internal Costs (4%)	$ 15,422	
			Total Cost (rounded per km)	**$ 520,000**	

EXCLUDES
Drainage works

17 ACTIVE TRANSPORTATION WAYFINDING

TRANSPORTATION MASTER PLAN
LOOKING AHEAD

THE CITY OF Waterloo

alta PLANNING + DESIGN

Date: 23 January, 2020

To: Chris Hodgson, City of Waterloo

From: Kalle Hakala, Alta Planning + Design

Cc: Kate Whitfield, Alta Planning + Design

Chris Dedman, City of Waterloo

Gene Chartier, Paradigm Transportation Solutions Limited

Re: **City of Waterloo TMP – Active Transportation Wayfinding Memorandum**

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1 Introduction

Wayfinding is integral to the success of the City of Waterloo's active transportation network. The following memorandum provides a review of applicable design guidance and best practices and Waterloo's existing approach. This memorandum includes a benefits statement and recommendations for prioritization.

What is Wayfinding?

Wayfinding is a system of signs, markings, maps, and other signifiers by which people follow a route from one place to another. It is intended to help people navigate their surroundings intuitively and efficiently. Wayfinding is used in a variety of settings and scales, such as in airports, highways, ski areas, and university campuses. Likewise, wayfinding is often used to help people navigate a city's active transportation network.

1.1 Benefits of Wayfinding for the Active Transportation Network

A robust wayfinding system can have many positive outcomes for the active transportation system. Some of the benefits of wayfinding are described below.

Orientation

Wayfinding can help people orient themselves quickly. It allows users to better understand where they are going and how it relates to other locations either on a map or through signage with destinations included. In addition, wayfinding can assist users in understanding how the active transportation network fits together as a whole. Wayfinding is perhaps additionally important for an active transportation network as trails may not follow the urban structure (e.g. the street grid), and thus users may easily become disoriented.

Route Planning

Wayfinding provides people information to enable them to plan their routes effectively. Further, it allows people to make more accurate judgements on travel time, which can otherwise be a barrier.

Active Transportation Promotion

Wayfinding can make cycling more comfortable for new or casual cyclists by helping them feel more confident in knowing where they are going. It also increases awareness of active transportation by communicating to other road users, such as motor vehicles, the presence of active transportation infrastructure. Wayfinding can more efficiently use existing infrastructure for active transportation purposes, such as by using minor streets to make connections between segments of pathways.

Placemaking

Wayfinding encourages people to discover new destinations by allowing them to confidently explore the network and learn about destinations listed on signage. Wayfinding can be used as a placemaking tool by giving places an identity and by integrating with the cultural environment.

2 Design Guidance Review

2.1 Design Guidelines

The following documents were reviewed:

- NACTO Urban Bikeway Design Guide (2014)
- OTM Book 18 (2013) and Draft update (2020)
- OTM Book 7 Temporary Conditions (2014)

The two most relevant documents with wayfinding guidance for active transportation are the NACTO Urban Bikeway Design Guide (2014) and the Draft Ontario Traffic Manual Book 18 (2020). These two documents take a similar approach to wayfinding, the details of which are described under the next five headings.

Signage Type

There are three main types of signs that are recommended for use in wayfinding for cycling routes:

- **Decision signs:** These signs advise of an upcoming junction and provide information about the possible routes, such as distance to destinations. They are usually placed 40 to 50 m before a decision point and include destinations, travel distance/time, and directional arrows
- **Turn signs:** These signs notify users of an immediate turn, and are placed 5 to 10 m before a turning point
- **Confirmation signs:** These signs are used to reassure users that they are on the correct route. They are usually placed 20 to 30 m after a decision point and repeated at least every kilometre

Figure 1 - Fingerboard decision sign in Waterloo (Photo by Alta)

In addition to the main signs above, other signs may be useful in certain circumstances. These include:

- **Fingerboard signs:** These provide detailed information about possible routes at major junctions (Figure 1)
- **Trailhead/information kiosks:** These may include maps, interpretation panels, and other detailed information about the trail network (Figure 2)
- **Street name signs:** These may include symbols to highlight active transportation infrastructure or route
- **Distance markers:** These are used to show distance from a single point
- **Bike route map signs:** These show a map of the entire route or the network
- **Gateway signs:** These may be used at the entry to a neighbourhood or park [1] [2]

Figure 2 – Trailhead sign with map and interpretation panel, Bellingham, WA (Photo by Alta)

Sign Design

The NACTO guide suggests the use of "Clearview Hwy" typeface as it is consistent with other US guide signs, while Draft OTM Book 18 recommends a typeface that is consistent with the local context. The latter document also recommends sign size, colours, and amount of text should be designed to be read by cyclists travelling at average speed.

Destination hierarchy

Destinations should be used on wayfinding signage to give context to the users' location and so they know where each route leads to. Destinations included on the signs differ depending on where the destination is in relation to the users' location and the importance of that destination. There are three levels of destinations:

- **Primary:** These are city-wide destinations and as such are the largest and most important destinations in the city. Primary destinations may include locations such as downtowns, universities, and major parks. Generally, they would be listed on signs up to 8 km away
- **Secondary:** These are destinations that are significant for a sector of the city, and may include neighbourhoods, light rail transit stations, hospitals, or shopping centres. They would usually be listed on signs up to 2 km away
- **Tertiary:** These are destinations that are relevant for the local area, and may include community centres, schools, or on-street bikeways. They are generally listed on signs up to 1 km away[3] [4]

Pavement Markings

Pavement markings can be used in conjunction with wayfinding signage to guide users along routes. They are especially helpful in areas where signage might be obscured or in particularly complex junctions. This might include directional "sharrows" or route branding.[5]

Maintenance

Like all signs, wayfinding signs eventually need replacement due to weathering, new information, or accidental or willful destruction. Municipalities should keep track of wayfinding signage characteristics to ensure replacement occurs at the end of its lifecycle or when in need of updating.[6]

Wayfinding Principles

Draft OTM Book 18 (2020) includes a list of seven principles to guide a wayfinding system, as follows:

- **Simplicity:** Keeping the information straightforward yet with enough detail to be helpful
- **Consistency:** Signage that has a uniform design and is located consistently
- **Conspicuity:** Signage that is directed at cyclists
- **Relevance:** Ensuring that destinations and facilities included on signs are relevant to users
- **Continuity:** Signage that allows users to interpret them while they keep moving
- **Integrative:** A system that connects routes as part of whole network and is not isolated
- **Universality:** Designed to be accessible for all ages and abilities[7]

Temporary Conditions

Ontario Traffic Manual Book 7 Temporary Conditions (2014) sets out guidelines for construction detours, which can also be applied to pedestrian and cyclist facilities. Of particular significance to wayfinding is Figure TL-42(i), which describes detour and alternative route signage.[8]

2.2 Accessibility for Ontarians with Disabilities Act, 2005

The Accessibility for Ontarians with Disabilities Act, 2005 (AODA) indicates that new or reconstructed recreational trails must meet certain accessibility standards, such as a minimum width and uniform surface. Recreational trails are defined as "public pedestrian trails that are intended for recreational and leisure purposes".[9] The Act has implications for wayfinding in that the trail must have signage at the start of the trail that includes details on the trail's accessibility attributes (Figure 3). In addition, there are specific design requirements for the wayfinding signage to ensure they are easily legible.

80.9 (1) 8. A recreational trail must have at each trail head signage that provides the following information:

i. The length of the trail.

ii. The type of surface of which the trail is constructed.

iii. The average and the minimum trail width.

iv. The average and maximum running slope and cross slope.

v. The location of amenities, where provided. O. Reg. 413/12, s. 6.

(2) The signage referred to in paragraph 8 of subsection (1) must have text that,

(a) has high tonal contrast with its background in order to assist with visual recognition; and

(b) includes characters that use a sans serif font. O. Reg. 413/12, s. 6.[10]

Figure 3 - Confirmation sign with accessibility information for Iron Horse Trail, Waterloo (Photo by Alta)

3 City of Waterloo Current Practice

3.1 Context for Wayfinding

The City of Waterloo has an existing active transportation network and context that is appropriate for wayfinding. It forms part of the larger urban region, and as such is integrated with the surrounding municipalities, in particular the adjoining City of Kitchener. In this sense, the City of Waterloo is not an island unto itself. Within the City, there are several major destinations. Uptown Waterloo is one of the three traditional downtowns in the Region and is identified as an urban growth centre where intensification is directed. The City is home to two major universities, one college (Conestoga College – Waterloo Campus), and associated research parks which are major destinations in their own right. There is also a major mall (Conestoga Mall), and several large parks, including Laurel Creek Conservation Area, Waterloo Park, and Bechtel Park. Eight of the 18 ION light rail stops are in the City of Waterloo, and these connect many of the major destinations.

The City has an extensive and diverse active transportation network, which connect major destinations to neighbourhoods. The network includes:

- 109 km of community trails
- 32 km of multi-use paths
- 130 km of conventional bicycle lanes

- 10 km of separated bicycle lanes
- 21 km of signed bike routes
- 545 km of sidewalks
- 18 km of walkways

3.2 Existing Wayfinding System

The City of Waterloo has an existing wayfinding system in place. This system uses the NACTO guidelines described above for direction on design of the system. This includes use of a hierarchy of destinations (such as RIM Park), including distances and time to destinations, and using sign types that differ by function. The major sign types consist of decision signs, confirmation signs, and fingerboard signs (the latter acting as decision signs for major junctions). It does not appear that turn signs, as described in Section 2.1, are currently used by the City of Waterloo. Some of the major trails (such as the Iron Horse Trail) include the trail name and logo, as well as the trail's characteristics, such as trail length, surface material, width, slope, and amenities. There is also a main trailhead pavilion for the Trans Canada Trail located at the south end of Waterloo Park by Silver Lake (Figure 4). This pavilion includes a map of the City's active transportation network. The City also adds signs indicating where a trail is not winter maintained as shown in Figure 5.

At present, the wayfinding system is limited to the High Priority Trail Network and is gradually expanding to other on- and off-road routes. All signs in the existing system are inventoried within the City's asset management system and geo-located in the GIS database for ease of replacement.

The Region of Waterloo also has their own similar wayfinding signage system, as shown in Figure 6.

Figure 4 - Trans Canada Trail Pavillion in Waterloo Park (Photo by Alta)

Figure 5 - Trail with no winter maintenance (Photo by Alta)

Figure 6 - Region of Waterloo wayfinding sign (Photo by Alta)

4 Summary and Recommendations

4.1 Summary of Findings

Wayfinding is a useful tool to assist people in orienting themselves, planning their routes, and opening people up to the wider active transportation network. The City of Waterloo includes many major destinations and an existing active transportation network that is ideally linked with a wayfinding system. The design guidance and regulatory requirements provide straightforward and logical direction on how to implement a wayfinding system. The City of Waterloo's existing wayfinding system already meets most of the recommendations of the design guidelines cited.

4.2 Recommendations

General recommendations

The existing City of Waterloo wayfinding system is consistent with the recommendations of NACTO and Draft OTM Book 18, specifically with respect to destination hierarchy. It uses decision signs and confirmation signs, but turn signs as described in Section 2.1, are not commonly used in the City of Waterloo. Use of such signs would provide a valuable tool for users to navigate the active transportation network.

It is recommended that the existing system be continued with the additional inclusion of turn signs at junctions. This system should be extended to the remainder of the active transportation network in line with the priority locations set out in Section 4.3. Other optional types of signs, such as trail head signs, should also be added at major junctions or congregation points.

Accessibility

For new or rebuilt recreational trails that must be designed to be AODA compliant, signage must also meet the standards set out by the AODA (and cited in Section 2.2). The additional accessibility information on the signage is

required on signs at the start of the recreational trail. It is recommended that a standard sign template similar to that in Figure 3 be developed for use at the start of all recreational trails, and adapted accordingly.

Ongoing maintenance and temporary conditions

The existing GIS database and inventory that the City of Waterloo uses should be maintained and expanded to include all new signage added to the system to ensure ongoing maintenance.

Temporary conditions, such as construction projects, can be a potential detriment to cyclists and pedestrians if they are not able to easily follow their route through the affected area. There should be a process for all construction projects to consider impacts on active transportation infrastructure and ensure an appropriate detour is in place, and that that detour is signed accordingly.

Coordination with other jurisdictions

As the City of Waterloo is integrated into the Region of Waterloo and with surrounding municipalities more than most cities, it is important to ensure that it is not acting on its own. An ideal wayfinding system integrates with those in other local jurisdictions, including the Region of Waterloo and the City of Kitchener, and Grand River Transit. This includes the use of consistent sign type and design, and use of corresponding destinations (e.g. using ION stations at the same level of the hierarchy).

Signage clutter

Implementing a wayfinding system means placement of additional signs throughout the city, which could contribute to over-signage or signage "clutter" in the public realm. There are several ways that over-signage can be mitigated. One strategy is to use pavement markings as supplementary to signage, which can also help to eliminate the need for redundant signage. This was used as a means of reducing signage clutter in a wayfinding strategy in Billings, MT.[11] It should be noted that additional pavement markings require regular maintenance, and can be obscured by leaves and snow during certain times of the year and therefore should be not be used on its own.

The issue of signage clutter can also be addressed by using a coordinated and integrated approach between internal departments and other jurisdictions (e.g. Region of Waterloo, Grant River Transit, Grand River Conservation Authority). It is possible to rely on existing wayfinding signage for motor vehicles if it is appropriate for bicycles and pedestrians.[12] For example, a street name blade sign is used by car drivers, bikes, and pedestrians alike to understand the street network, and thus additional street name signage at these locations is not necessary. Coordination with other signage by sharing posts is another way of reducing clutter.[13]

4.3 Prioritization

The existing wayfinding system should be expanded to include additional parts of the active transportation network. The following criteria should be used to determine prioritization:

1. **High Priority Network (HPN):** The HPN will be updated through the TMP and any new addition to the network should be a priority for wayfinding as it forms the backbone to the overall active transportation network.
2. **Routes accessing major destinations:** Routes leading to and from major destinations, such as the universities or ION stations, should be a priority.
3. **Unintuitive routes:** Routes that have multiple turns or jogs that may not be easy to follow for users should be a priority as these are routes that may confuse casual users.

4. **Routes through barriers:** Routes that provide a safe crossing of a major barrier, such as across Highway 85 or Laurel Creek, should be a priority as they are critical to expanding the access to areas on either side of the barrier.
5. **Connections to HPN:** Routes that are directly connected to the HPN should be a priority to provide continuity with the wayfinding system already used on the HPN.

4.4 Benefits Statement

Wayfinding can help make better use of the active transportation network by providing people a tool to orient themselves and plan their routes to encourage the best paths of travel. It can increase awareness of active transportation and contribute to placemaking, thereby leveraging the investment in active transportation to advance other City goals.

5 References

[1] National Association of City Transportation Officials. *Urban Bikeway Design Guide.* (2014).
[2] Queen's Printer for Ontario. *Ontario Traffic Manual, Book 18, Cycling Facilities.* (2013), (Draft update 2020)
[3] National Association of City Transportation Officials. *Urban Bikeway Design Guide.* (2014).
[4] Queen's Printer for Ontario. *Ontario Traffic Manual, Book 18, Cycling Facilities.* (2013), (Draft update 2020)
[5] National Association of City Transportation Officials. *Urban Bikeway Design Guide.* (2014).
[6] Ibid.
[7] Queen's Printer for Ontario. *Ontario Traffic Manual, Book 18, Cycling Facilities.* (2013), (Draft update 2020)
[8] Queen's Printer for Ontario. *Ontario Traffic Manual, Book 7, Temporary Facilities.* (2014).
[9] Queen's Printer for Ontario. *Accessibility for Ontarians with Disabilities Act, O.Reg 191/11* (2005) Retrieved from: https://www.ontario.ca/laws/regulation/110191#BK99
[10] Ibid.
[11] Alta Planning and Design, *Billings Wayfinding Signage Plan: Wayfinding Best Practices.* (2019).
[12] Queen's Printer for Ontario. *Ontario Traffic Manual, Book 18, Cycling Facilities.* (2013), (Draft update 2020)
[13] Ibid.

18 WINTER MAINTENANCE FOR ACTIVE TRANSPORTATION

Date: April 28th, 2020

To: Christopher Hodgson, City of Waterloo

From: Nataliya Pekar, Alta Planning + Design

Cc: Chris Dedman, City of Waterloo

Kate Whitfield, Alta Planning + Design

Gene Chartier, Paradigm Transportation Solutions Limited

Re: **Waterloo TMP – Winter Maintenance for Active Transportation Memo**

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1 Introduction

As part of its Transportation Master Plan (TMP) update, the City of Waterloo (City) has conducted a review of best practices related to winter maintenance policies and procedures for active transportation facilities. The plan establishes a policy framework to encourage a multi-modal system of walking, cycling, and transit. By extension, as the City expands its network of sidewalks, trails, and cycling facilities, so expand requirements and considerations for winter maintenance. Policies for snow clearing and ice treatment have a direct impact on whether people choose to ride bikes or walk in the winter months, affecting access to transit, accessibility for vulnerable users, and safety, all of which must be considered to create an all ages and abilities network.

Decision-making on winter maintenance in the City of Waterloo should reflect broader municipal and regional policy goals on encouraging a greater modal shift towards alternate modes of transportation. The Provincial Policy Statement (PPS), Places to Grow Act and Growth Plan, Region of Waterloo Official Plan, Region of Waterloo TMP, and City of Waterloo Official Plan and Strategic Plan all reference investment in sustainable transportation, while the Walk Cycle Waterloo Region (2015) includes a specific and comprehensive winter network action plan. With these directives in mind, the following review provides a resource on winter maintenance by investigating best practices from comparable cities and design guidance, and comparing findings in a discussion that includes a list of potential avenues for future investment. This memo also includes a benefits statement and a review of potential impacts on capital, operating and maintenance practices and costs due to increased maintenance on active transportation facilities.

For the purposes of this memo, the focus for winter maintenance is snow removal, snow clearing, and ice accumulation. Other topics related to winter maintenance, but which are not reviewed within this memo, include designing for winter, debris removal, illumination, covered bike parking, asset management (including impact of freeze-thaw cycles and salts), environmental impacts of de-icing salts, and communications.

1.1 Why do People Walk and Bike in Winter?

Investment into winter maintenance of bikeways and pedestrian facilities removes barriers to walking, riding bikes, and taking transit in winter months by improving safety, accessibility, and comfort with the benefit of increasing mode share for sustainable modes of transportation.

Why do people walk and bike in winter?[1]

- Some people walk and bike in winter because they prefer to, while others do so because it is the most rational or economically viable option
- People walking and biking in winter are making the same kinds of trips as those they make during the rest of the year, and the same kinds of trips as people in motor vehicles
- People walking and biking in winter are going to and from transit services
- Also, of note: many of those who walk and bike in winter are people with disabilities, older adults, and children

The list above is not meant to be exhaustive. People walk and bike in winter for recreational reasons and as an opportunity to improve mental and physical health. The list of reasons is extensive (i.e., access to nature and social interaction, connection to one's neighbourhood, etc.).

2 Provincial Context - O. Reg. 239/02: Minimum Maintenance Standards for Municipal Highways

In May 2018, significant changes were made to O. Reg. 239/02 – the Minimum Maintenance Standards for Municipal Highways. O. Reg. 239/02, henceforth referred to as "the regulation", establishes standards for the maintenance of municipal roadways and sidewalks, including snow, ice, potholes, shoulders, cracks, debris, lights, signs, and traffic controls. As part of the 2018 update, specific standards for snow and ice maintenance of bicycle lanes and sidewalks were added for the first time.

Bicycle Facilities

The regulation defines a "bicycle facility" as on-road and in-boulevard cycling facilities, and further defines a "bicycle lane" as the portion of the roadway designated for exclusive or preferential use of cyclists by pavement markings, signage, a physical or a marked buffer. The "roadway" is defined as the part of the highway that is ordinarily used for vehicular traffic, meaning that any reference to a bicycle lane in the regulation applies to on-road bicycle facilities, specifically traditional bicycle lanes, buffered bicycle lanes, and on-road physically separated bicycle lanes, but not to in-boulevard multi-use trails and raised cycle tracks.

The standards for clearance of snow accumulation for bicycle lanes are shown in **Table 1**. The requirements are based on roadway class, a designation determined by posted speed and average annual daily motor vehicle traffic (AADT), where a higher standard of maintenance applies to roadways with higher speed limits and traffic volumes. Under normal conditions, a municipality is required to clear the facility of snow after becoming aware that the minimum accumulation has occurred and within the required amount of time after the snow accumulation has ended. The regulation also establishes a minimum width of the lesser of 1.0 m or the actual bicycle lane width to be cleared for a bicycle lane.

Table 1: Snow Accumulation Standards - Bicycle Lanes

		Required Response Time for Snow	
Class of Highway or Adjacent Highway	Minimum Snow Accumulation	Roadways	Bicycle Lanes
1	2.5 cm	4 hours	8 hours
2	5 cm	6 hours	12 hours
3	8 cm	12 hours	24 hours
4	8 cm	16 hours	24 hours
5	10 cm	24 hours	24 hours

Under the regulation, a municipality is allowed to declare a "significant weather event", defined as "an approaching or occurring weather hazard with the potential to pose a significant danger to users of the highways within a municipality." In such a circumstance, the municipality is not required to start clearing until the weather event has ended, after which the clearing time limit takes effect.

Sidewalks

A sidewalk is defined as "the portion of a highway specifically set aside or commonly understood to be for pedestrian use, typically consisting of a paved surface but does not include crosswalks, medians, boulevards, shoulders or any part of the sidewalk where cleared snow has been deposited". The standard for addressing snow accumulation on sidewalks is to reduce the snow to a depth less than or equal to 8 cm within 48 hours after snow accumulation has ended. A minimum width of 1.0 m is to be provided.

Similar to that of bicycle lanes should a "significant weather event" be declared, the municipality is not required to start clearing snow accumulation until the weather event has ended and the municipality deems it appropriate to do so, after which the clearing time limit takes effect.

Ice Formation

The regulation also includes standards for managing ice formation. For bicycle lanes, shown in **Table 2**, municipalities are to monitor weather and patrol for 24 hours preceding potential ice formation, where preventative treatments are to commence and meet response times if a high probability of ice formation is determined. If ice formation does occur, response times are provided for roadway treatment. Similar to snow removal, significant weather events delay the requirement for treatment to start until after the event has ended. These requirements are consistent with those for roadways. For sidewalks, the same procedures are applicable but require ice prevention within 48 hours of determining that there is a substantial probability of ice formation, or treatment within 48 hours of discovery of ice formation.

Table 2: Response Times for Ice Treatment Roadways / Bicycle Lanes

Class of Highway or Adjacent Highway	Response time for ice prevention	Response time for ice treatment
1	6 hours	3 hours
2	8 hours	4 hours
3	16 hours	8 hours
4	24 hours	12 hours
5	24 hours	16 hours

In summary, the regulation establishes clear standards for how municipalities are to remove snow and ice from sidewalks and on-road bicycle facilities, including traditional bicycle lanes, buffered bicycle lanes, and on-road physically separated bicycle lanes. These standards allow a longer response time for bicycling facilities and sidewalks compared to roadways. Standards are not provided for in-boulevard multi-use trails and raised cycle tracks, so it is presumed that the regulation does not obligate municipalities to clear these facilities of snow and ice.

Municipal Approaches to the new Minimum Maintenance Standard

Municipalities have been reviewing their existing standards to ensure compliance with the updated Minimum Maintenance Standard for Municipal Highways. As part of the Region of Waterloo Separated Bike Lane Pilot, the Region states that the separated cycling facilities will be maintained "to the same standard as the adjacent driving lane for motor vehicles."[2] A report was completed by the City of Kingston outlining the changes required in maintenance activities in order to comply with the regulation. In the report, it is acknowledged that road clearing often pushes snow into the bicycle lane. To meet the new standard, Kingston has moved to remove snow and haul it away in lieu of roadside storage. In addition, a new snow blower attachment was approved in their 2019 budget and the staff report indicates that additional equipment and staffing may be needed in future years to meet the standard.[3]

A report for the City of Cambridge on complying with the updated regulation recommended that bicycle lanes that are adjacent to both the road and sidewalk should be designated as seasonal bicycle lanes, except where measured bicycle volumes warrant high priority snow lifting. Bicycle lanes in these locations are noted as being impractical to clear as the maintenance activities on the road and adjacent sidewalk push snow into the bicycle lane.[4] This approach is not considered best practice but an example of how a municipality is addressing resource allocation and prioritization in response to the new regulation.

3 City of Waterloo Current Practice

The City has practices in-place for winter maintenance of active transportation infrastructure such as sidewalks and bicycle facilities. These existing strategies and procedures are summarized below, using information from the City's public website, internal discussions during the TMP process, and detailed notes from a meeting between operational staff from Transportation, Parks, etc. and Alta Planning + Design on March 6th, 2019.

The City, at a minimum, clears in accordance with Ontario regulations, detailed in **Section 2**, including all regional roads on behalf of the Region of Waterloo. The City also provides service alerts related to snow-related parking bans.

3.1 Clearing Standards

Table 3 summarizes the standards to which the City completes snow clearance for active transportation infrastructure. As soon as snow or ice reaches an established level, maintenance crews begin removal. On-road bike lanes are cleared of ice and snow per O.Reg.239/02, while other cycling facilities are not explicitly mentioned. Roads are cleared after 5 cm, 8 cm, or 10 cm depending on the class of roadway.

Table 3: City of Waterloo Existing Snow Clearance Standards and Practices

Facility Type	Jurisdiction	Standard
Major Arterial	Transportation	6 hours (12 for bicycle lanes per O.Reg.239/02)
Major Collectors/Bus Routes	Transportation	12 hours (24 for bicycle lanes per O.Reg.239/02)
Residential Streets (class 4)	Transportation	16 hours (24 for bicycle lanes per O.Reg.239/02)
Cul-de-sac/Minor Residential (class 5)	Transportation	24 hours
Multi-Use Trails	Parks	Trail clearance begins on commuter trails with a minimum of 5 cm of snow. Spurline, Iron Horse, and Laurel trails are prioritized for cleaning while other winter-maintained trails are cleared within 48 hours after the snow has stopped falling to a standard of bare pavement. Where trails are not maintained a sign is posted.
Sidewalks	Shared responsibility for clearance between City and property owners	The city clears sidewalks not connected to a residence or business within 48 hours of the end of a snow or ice storm per the Municipal Act, with increased priority for areas with increased mobility needs[5]. Property owners' clear sidewalks connected to a residence or business within 24 hours of the end of a snow or ice storm per By-Law No.09-156

3.2 Equipment and Methods

A summary of equipment types and procedures used to clear active transportation facilities by maintenance crews at the City of Waterloo is provided below:

Transportation

- On-road and conventional bicycle lanes without physical separation are cleared by the Transportation group, using conventional truck-mounted plow blades
- The Transportation crews clear the majority of snow using the wing of a truck-mounted plow blade. Parks crews use tractor plows to clear the remainder of snow down to pavement and move snow into amenity space
- For bike lanes separated by a mountable curb, truck-mounted plow blades are also used for initial clearing
- Salt is used as a primary resource and sand when salt is in short supply. Brine is used by the Transportation crews in extreme cold (−10°C)

Parks

Two types of equipment are used by the Parks crews:

- Trackless vehicles are used for sidewalk plowing and trails (8 of these are available in the fleet). These can be used for physically separated facilities (ex. King St. raised cycle tracks). They are used where there are bollards but require 1.6 m minimum clearance. These also assist Transportation crews by clearing areas such as refuge islands overnight when traffic is reduced, and during the day they provide spot cleanup.
- Tractors with box scrapers are also used. These require minimum 3 m clearance and may have a salter on the back. They can be used for year-round maintenance.

Other

- Grand River Transit clears bus stops
- Planters are left in place during the winter, but are designed and placed with snow storage in mind
- Where wide buffers (0.3 m buffer used for bollards in uptown bike lane) have been employed, clearing has switched from Transportation to Parks
- The City posts permanent signs on trails that are not winter maintained

Figure 1: Tractor with V-Blade Plow (Waterloo)

Figure 2: Trackless with V-Blade Plow (Waterloo)

Figure 3: Pickup Truck Plow (Waterloo)

Figure 4: Sweeper / Broom attachment (Waterloo)

3.3 Challenges and Discussions with Staff

On March 6th, 2019, a meeting between operational staff from Transportation, Parks, and other groups was held with Alta Planning + Design present. Detailed notes were taken regarding practices and challenges in clearing and expanding the clearing for active transportation facilities. Additional emails were also sent from staff. All of this information is summarized below.

- Specific to the broom attachment to trackless vehicles used for sidewalk plowing and trails (**Figure 4**):
    - Broom cleaning on trails is only appropriate for low volumes of snow (1")
    - Broom cleaning is not effective on sidewalks due to limitations of the equipment
    - Not an option to leave broom attachment on trackless vehicles at all times, along with other logistical limitations (i.e., cannot come and go to vehicle yard to pick up broom attachment)
    - Common request from the public for increased level of use of the broom attachment
- Bus stop clearance can result in snow dump in bike lanes
- Bollards pose a challenge, bike lanes separated by bollards in 0.3 m buffer are now plowed by the Parks crews
- Separated bike lanes pose a challenge because of snow clearing and road sweeping
    - Transportation crews prefer cycle tracks at grade with sidewalk for ease of clearing
- Complexity is introduced due to increasing fleet of specialty equipment
- Stone dust is hard to manage due to frozen blocks of ice, stone dust trails are being paved
- Some green thermoplastic paint has a poor life-span (King St.) which may be due to winter maintenance issues
- Barrier curbs are more challenging to clear than mountable
- Staff concerns related to environmental impacts of increased salt use for storm water and creeks
- Staff concerns related to storage capacity and cost of off-site storage implications at current City of Waterloo Service Centre with regards to increasing fleet
- Complexity in coordination between Transportation and Parks staff for segregated bike lanes
- Staff concerns regarding increased volume of work and clearing without corresponding increase or re-allocation of resources

Below are photos taken in the City of Waterloo of winter maintenance practices.

Figure 5: Laurel Trail near Silver Lake

Figure 6: Seagram Drive near Laurier-Waterloo Park Station

Figure 7: Rolled Curb on Davenport Road to Facilitate Snow Clearing

Figure 8: Transit Stop on Columbia Street W

Figure 9: Lexington Road over Conestoga Parkway (facing NE)

Figure 10: Lexington Road over Conestoga Parkway (facing SW)

3.4 TMP Stakeholder Discussions

In the Phase 1 – Engagement Summary Report of this TMP, results from digital and in-person engagement undertaken in 2019 include several references to winter maintenance. Participants who use active modes of transportation expressed concern with infrastructure maintenance during the winter, specifically noting:

- Lack of winter maintenance is a barrier to walking and riding bikes
- Better winter maintenance is an opportunity to make walking and rolling easier
- Concerns regarding a lack of safety, difficult terrain, snow dumping into bike lanes, and winter conditions prevent people from cycling
- Winter maintenance of pathways/sidewalks to and from bus shelters would improve transit use and access

Winter sidewalk maintenance was also a key note amongst participants who shared concerns for public safety, especially for vulnerable populations.

3.5 City of Waterloo Winter Control Modernization Review (2019)

The City received funding from the Province of Ontario Audit and Accountability Fund for a review of Winter Control operations, the aim of which was to identify opportunities to modernize and improve the efficiency of winter operations.

The report was approved by Council in November 2019 and includes the following summary of opportunities related to Trails, Sidewalks and Laneways to:

- Analyze slip and fall data
- Introduce trail equipment rotation
    - For example: The City can rotate trail equipment between the Service Centre and Waterloo Park to ensure that utilization levels of equipment are distributed more evenly. This is predicated on monitoring the equipment performance and average maintenance costs between the two sets of trail equipment as the more economical machines should be used more. At the end of each winter season, equipment can be rotated based on this data.
- Maximize equipment utilization
- Enhance trail equipment
    - For example: The City can source enhancements or new attachments to existing equipment used for trail maintenance to address the changes in trail infrastructure such as street furniture or increased trail widths
- Introduce tiered levels of service for bike lanes and trails
    - For example: The City can offer tiered levels of service delivered to bike lanes and trails in order to deliver a higher service level and reliability to the most active routes. Trail user count data can be leveraged to ensure a data-driven approach is applied to identify the City's most active routes. This represents a prioritization (winter priority network), where some routes receive higher service level than others that may accept lower maintenance, however all routes remain open and cleared to minimum standards set by O. Reg. 239/02.

The Winter Control Modernization Review (2019) provides actionable recommendations organized by theme. The potential net annualized efficiency or cost saving and service or community impact of each

recommendation is described in the report. The report provides a summary for the City's consideration on how to proceed with the recommendations associated with each opportunity.

4 Design Guidance Review

Two guidance documents were selected for review and are listed below:

- *Winter Bike Lane Maintenance: A Review of National and International Best Practices (Alta Whitepaper, 2014)*
- *NACTO Urban Street Design Guide*

4.1 Winter Bike Lane Maintenance: A Review of National and International Best Practices (Alta Whitepaper, 2014)

Winter Bike Lane Maintenance: A Review of National and International Best Practices (2014), is a white paper published by Alta Planning + Design. The paper discusses snow clearance, ice treatment and removal, and best practices for prioritization with the goal to provide functional cycling facilities year-round.

Snow Clearing

Clearing snow from bicycle lanes can require special considerations for equipment. For instance, where bicycle lanes are physically separated from traffic, standard truck mounted plow blades may be unsuitable for snow clearing. Equipment that has been deployed in other jurisdictions include a pickup truck mounted plow blade or smaller vehicles such as tractors, ATVs with blades, or a tracked snow removal vehicle such as the Bombardier SW4S. For lighter snowfalls, brushes may be used as an alternative to plows, and for heavier snowfalls, blowers are more effective.

Ice Treatment and Removal

Ice formation on bicycle facilities can be treated both proactively and reactively. The proactive approach involves anticipating conditions which could result in ice and applying de-icing materials two hours in advance of the freezing event. The North Dakota DOT reports that managing ice proactively uses one third as much de-icing material as reactive treatments.

Treatment of ice involves applying materials that either melt the ice, or improve the traction of bicycles traveling over ice. Treatments materials include:

- Salt, which is effective up to -9 ℃ (or up to -18 ℃ with additives), however, salt treatment requires tires to crush it on the roadway, where bicycle tires may not meet this requirement, and salt is also corrosive and can damage bicycles as well as impacts to storm water quality
- Pre-wetted salt (brine) works faster, is more effective, and requires less material than rock salt
- Additives to brine, such as beet juice or cheese brine are inexpensive, less environmentally damaging, and can improve the effectiveness of brine
- Sand and gravel, while they do not melt ice, provide traction in all temperature conditions. However, when these materials accumulate on the bikeway, they pose a hazard for bicyclists and should be cleared following a snow event.

Snow Storage

An important aspect of enabling the clearing of bicycle facilities is to ensure adequate storage for cleared snow in the design of bikeways. The paper recommends providing a minimum of 1.8 m of space between the curb and the sidewalk for snow storage outside of the roadway. For cities receiving higher volumes of snow, wider spaces are recommended. For example, Montreal prefers 2.4 m of storage space, and Ottawa prefers 2 to 3 m for storage space. Alternatively, a buffered or physically separated bicycle lane allows snow to be stored between the bicycle lane and the roadway. An impact of this strategy is reduced access for cyclists and potential snow melt across the bikeway. In order for this to be feasible with a moderate amount of snowfall, the paper recommends that a minimum buffer width of 1.5 m be provided. During heavy snowfall events, on-street parking spaces can alternatively be used for snow storage.

Constructing bicycle lanes to a recommended width of 1.8 m allows some contingency width in the bicycle lane, where snow storage can occupy some of the lane without rendering the facility unusable. The City of Ottawa and the Halifax Regional Municipality prefer 1.8 m of clearway to facilitate snow clearing. For more information on lane width considerations, see the **Lane Widths Memo** of this TMP.

Prioritization

With limited resources for snow removal, it is important to prioritize clearing of routes that will yield a higher benefit to the bicycle network. This can be done with a variety of strategies:

- Upgrading the priority of streets with bicycle lanes to the highest in snow removal classifications, a strategy employed by the City of Calgary
- Establishing a priority network of bicycle routes for winter clearing, which comprises a fraction of the overall bicycle network, employed in Montreal, Toronto, and Ottawa (see **Section 5**)
- Establishing a distinct classification system for bicycle routes, with different clearing response variables for each class, employed in Järvenpää, Finland

Snow clearance standards for off-road paved trails should be considered as well, especially when these facilities are important for transportation purposes, rather than recreation. The Wisconsin DOT prioritizes clearance of these routes based on usage volumes, destinations served, and whether they provide key connections, such as the crossing of a river or roadway.

4.2 NACTO Urban Street Design Guide

The NACTO Urban Street Design Guide was created to support roadway design in urban environments that promotes streets that are safer, more livable, and more economically vibrant. The guide provides commentary on design as it pertains to winter maintenance of physically separated bikeways which are a challenge due to limitations for equipment and snow storage space. Several strategies are noted below:

- NACTO does not recommend snow storage in the buffer zone of a physically separated bicycle lane, as snow melt across the bicycle lane can freezes and create icy conditions - implementing a raised median between the vehicle lane and bicycle lane can address this design issue
- NACTO recommends designing separated bicycle lanes at sidewalk level to simplify winter maintenance by providing a greater width for clearing and allowing larger vehicles to be used
- NACTO suggests use of removable bollards or flexible delineators which can be taken out in winter months to allow large plows to clear bicycle lanes as a tool but not the end goal for established best practice

5 Review of Comparable Cities

A selection of comparable Canadian cities to the City of Waterloo were selected for review on the basis of proximity and climate. A summary of the local requirements for snow clearing of sidewalks and cycling facilities are summarized in **Table 4**.

- City of Ottawa
- City of Toronto
- City of Hamilton

Table 4: Summary of Practices in Comparable Cities

City	Sidewalks	Bicycle Facilities
Ottawa	Sidewalks are cleared after the end of a snowfall event within the following time commitments: • Downtown core: 6 hours • Downtown residential: 12 hours • Other residential: 16 hours • Intersections and pedestrian crossings: 16 hours • Bus stops: 24 hours Most sidewalks are cleared at 5 cm within 16 hours. The City does not clear snow from driveways or private sidewalks leading to a residence. Property owners are not required to clear sidewalks adjacent to their properties as these sidewalks are cleared by the city.	The City of Ottawa has a 40 km Winter Cycling Network prioritized in the area of the downtown core and are cleared to the standards of the adjacent roadway. • Winter cycling network cleared at 2.5 cm within 4 hours • Major arterial and collector roads are plowed at the start of accumulation • Secondary roads at 5 cm within 6 hours • Residential roads at 7+ cm within 10 hours On arterial roads, cycling facilities are maintained to bare pavement, while multi-use pathways are maintained to a snow packed standard. Snow removal is also scheduled when snow banks are encroaching on to 50% of the width of the bike lane.

Figure 11: Example of Snow Clearing Equipment in Ottawa

Figure 12: Example of Snow Clearing Equipment in Ottawa

Table 5: Summary of Practices in Comparable Cities (continued)

City	Sidewalks	Bicycle Facilities
Toronto	Clearance of sidewalks and transit stops is dependant on road classification, time of year, and severity of storm. High volume pedestrian routes (arterial roads, school zones, transit areas, and accessibility locations) require clearing at 2 to 8 cm within 15 hours. This threshold increases for larger storms to multiple rounds of 15 hours. Low pedestrian volume routes and transit stops (collector and local roads) are cleared after 2 to 8 cm has fallen within 48 hours after snowfall. 2 cm applies to December to February and 8 cm to April to November. The City does not clear snow from driveways or private approaches. In parts of the City, property owners are required to clear the sidewalks adjacent to their homes within 12 hours after a snow storm has taken place.	Bike lanes and cycle tracks are salted and/or plowed in accordance with the level of service of the adjacent roadway. A priority network of bike lanes and cycle tracks in the downtown are designated for increased service. All are required to be cleared to bare pavement. • Priority cycle tracks are cleared after 5 cm within 6 to 8 hours • Priority bike lanes are cleared after 5 cm within 48 to 72 hours • Arterial roads and streetcar routes to after 5 cm within 6 to 8 hours • Collector roads, bus routes, and local after 5 to 8 cm within 8 to 10 hours • Neighbourhood roads, after 8 cm within 14 to 16 hours For arterial and collector routes, thresholds are increased with severity of storms. The City also maintains the Martin Goodman Trail to bare pavement after 5 cm, plowing and salting within 6 to 8 hours
Hamilton	The City of Hamilton requires property owners and occupants to clear snow and ice within 24 hours after the end of a snow event from sidewalks adjacent to their property. Sidewalks are serviced no more than 24 hours after the end of a storm.	For cycling facilities, the City of Hamilton requires the following: • On-street bicycle lanes match the priority and requirements of the roadway which are 4 hours on major arterial roads, 8 hours on collector and steep residential roads, and 24 hours on residential and rural roads • Cycle tracks and hard surfaced in-boulevard paths begin clearance within 24 hours after end of snowfall • Hard surface trails not within the road right-of-way begin clearance within 48 hours after the end of snowfall • In heavy snowfalls, bike lane or wider curb lanes may be temporarily used for snow storage

5.1 Feedback from Operations Perspective

A part of the comparison with other Canadian cities, it may be helpful to consider feedback from an operations perspective. The following commentary was provided by City of Ottawa staff from the roads department when interviewed for a presentation in Ottawa's winter clearing network for the Winter Cycling Congress in Minneapolis in 2016:

- Variety of bikeway configurations
    - No single piece of equipment is perfect
    - Snow extraction for transport is more difficult
- Slow build of the Winter Priority Network
    - Work is absorbed by existing staff
    - Requires coding of work time to measure cost
- Scheduling the "beats" becomes more difficult
    - Consideration of staff and equipment organization for shifts

5.2 Discussion

The following discussion compares existing City maintenance procedures to those summarized from other municipalities and to best practices.

Bike Facilities

Both the City of Ottawa and the City of Toronto have the largest coverage for winter maintenance of cycling facilities with designated priority networks that have clearly communicated metrics for extent, quality, and speed of clearance. Both cities focus their priority networks downtown. For streets not within this network, on-street bikeways are cleared to roadway standards. In contrast, the City of Hamilton and City of Waterloo do not designate a priority network for cycling. The City of Hamilton clears hard-surface facilities in the right-of-way within 24 hours, and outside the right-of-way within 48 hours, while on-road facilities match prioritization and standards of the roadways.

Both Ottawa, Toronto, and Hamilton exceed O. Reg. 239/02 minimum requirements for timing and clearance. The City of Ottawa has the highest commitments, requiring removal at 2.5 cm and within 4 hours for the winter cycling network. In Toronto, a more complex system is adopted based on road classification and severity of storm. Priority cycle tracks are cleared to bare pavement after 5 cm of snowfall within 6 to 8 hours and priority bike lanes after 5 cm within 48 to 72 hours. Facilities on arterial and collector roads in both cities also see response times that exceed O. Reg. 239/02, where arterial roadways are cleared upon accumulation in Ottawa and at 5 cm within 6 to 8 hours in Toronto. The City of Hamilton maintains on-street bicycle lanes to match roadway priorities which exceed O. Reg. 239/02. Cycle tracks are maintained within 24 hours and hard surface trails within 48 hours. While the City of Waterloo designates commuter trails for clearance within 5 cm of accumulation to the standard of bare pavement, its clearance of on-road cycling facilities matches O. Reg. 239/02 and does not extend to in-boulevard facilities and pathways.

Sidewalks

The City of Ottawa has adopted a classification-based structure for sidewalk clearance depending on whether a sidewalk is downtown, residential, etc., with most sidewalks maintained after 5 cm within 16 hours. The City of Toronto clears some sidewalks, while others are left to property owners to clear within 12 hours. For

those it clears, high volume routes require clearing at a snow accumulation level as little as 2 cm within 15 hours, while lower volume routes are cleared at 2 cm within 48 hours. In Hamilton, most sidewalks are cleared by residents within 24 hours after the end of a snow event, those that are not connected to a residence or business are cleared within 48 hours. The same policy applies to the City of Waterloo. While Ottawa and Toronto exceed O. Reg. 239/02, which requires clearing at 8 cm within 48 hours, both Hamilton and Waterloo meet the minimum requirements.

Accessibility

Winter conditions in South-West Ontario create challenges for all modes of transportation, but notably the accessing of the active transportation system. These challenges are reflected in feedback to TMP engagement in **Section 3.4**. Notably, accessibility locations are recognized as high priority within the City of Toronto sidewalk clearing framework. The cities of Toronto, Ottawa, and Hamilton offer assistance for snow removal requirements for seniors and people with disabilities who cannot plow snow at their property. The City of Waterloo similarly offers a home support program that assists seniors with seasonal work including snow removal. The program, which has a long waiting list, connects property owners with services that will clear and plow for them, where the owner pays for the service.

Impact of De-Icing Salts

While not explored in-depth in this memo, environmental impacts of winter maintenance practices are a key consideration. In the City of Waterloo, residents rely on the water table for their drinking water. When developing policy and practices for winter maintenance, the following should be considered:

- Impacts to local ecosystems (flora & fauna) from de-icing salts
- Shortened lifespan of infrastructure due to impacts to buildings, etc.
- Impacts to drinking water

De-icing salts are a significant tool but not the only resource available. Proper use of salt with established maintenance strategies and incorporation of alternative treatments are important to mitigate negative environmental impacts.

6 Recommendations

The overarching recommendation is for the City to introduce sidewalk and cycling network specific standards that exceed minimum requirements in O. Reg. 239/02 by increasing sidewalk clearing and incorporating cycle tracks and in-boulevard facilities. This is in keeping with recent actions of the City administration and the goals of the TMP and other strategic plans and documents such as the Strategic Plan 2019-2022 and Accessibility Plan.

6.1 Priority Networks and Mapping

The Winter Control Modernization Review (2019) included a recommendation to create tiered levels of service for bike lanes and trails. The intended focus is to deliver a higher service level to the most active routes. Trail user count data would be the basis to apply a data-driven approach to identify the City's most active routes.

GIS and analytics work specific to active transportation, being undertaken as part of the TMP update, is an important element of route identification. Trail user count data, alongside other variables, contribute to the

identification of appropriate routes (i.e., destinations served and whether they provide key connections, such as the crossing of a river or roadway). Optional criteria for selection of networks for sidewalks, trails, and cycling facilities include:

- First and last mile around ION/LRT
- Minimum grid network

The update to the TMP is in its initial stages. The information in this memo is intended to inform this discussion and be used alongside Phase 2 consultation to develop details specific to priority route identification (i.e., location, policy/standards and performance metrics).

Secondary Network and Key Spot Improvements

The concept of a primary network is to prioritize clearing of routes that will yield a higher benefit to the active transportation network. It is also intended to introduce a level of reliability and predictability for the users. At the same time, additional standards would apply to the remainder of the network (i.e., secondary network).

In order to maximize the connectivity between trails and in some cases local street bikeways, there are also opportunities for key spot improvements. This could be in the form of route planning or other programming to improve snow clearing at connection points (see **Figures 13 and 14**). There is an opportunity to identify such locations through the GIS and analytics process specific to active transportation mapping, as well as through Phase 2 engagement for the TMP update.

As cities adjust traffic patterns to create bicycle or pedestrian priority streets, roadway connections are created where through traffic is permitted for active users but not for motor vehicles. Additional consideration is required related to snow clearing to continue access year-round. **Figure 13** is from an example in Ottawa where a street connection has been changed to prohibited through motor vehicle traffic as a commercial area transitions into a residential area.

Figure 13: Example of Context for Key Spot Improvements (Ottawa)

Figure 14: Community Shovel Program (Calgary)

In Calgary, a unique approach has been applied where a local street bikeway crosses a major arterial road. Through motor vehicle traffic is prohibited and bike movements are encouraged using a deliberate gap in the fence installed on a concrete pad. A community shovel program was created as depicted in the **Figure 14**.

Sidewalk Clearing

Phase 1 engagement showed public support for sidewalk snow clearing and the comparison to nearby cities in **Section 5** has revealed potential areas for improving service. Formation of a strategy for sidewalk clearing will be informed by comparison to nearby cities, analytics, and Phase 2 engagement, but should consider taking the form of a pilot project with a focus on priority routes, ION stations, and mobility/accessibility needs in communities. A selection of comments on sidewalk clearing from Phase 1 engagement is included below:

- "The bike lanes and sidewalks should be cleared first or at the same time."
- "If we give priority to sidewalks, trails and bike lanes before roads, people will be encouraged to take those modes. Students, people with disabilities and seniors should not be subject to that."
- "City-managed winter maintenance for sidewalks on main arteries - many residents along Albert and University, for example, are not clearing their sidewalks in the wintertime - at all. It makes for very treacherous walking. I am an able-bodied 45-year-old and I have trouble navigating the sidewalks in winter; I also worry for the safety of older residents, and those with limited mobility."
- "Sidewalk clearing in winter! Please raise my property taxes to pay for sidewalk clearing. Getting around in this city in the winter on foot is difficult. I have tried to make bylaw complaints, but they are almost always ineffective, for example, three attempts on the same property, with no action taken."
- "Sidewalks are terrible. Why are they not cleared in the winter by the City?"
- "Sidewalk snow clearing! It is nearly impossible to use active transportation or transit all winter because of snow/ice - and a huge accessibility barrier. Sidewalk snow clearing would open up so many barriers to alternate transportation."

As seen through comparison to nearby cities, typically sidewalk clearing is organized through policy measures. Some cities put heightened onus on private owners to clear sidewalks (Hamilton), others have tiered levels of service depending on area (downtown core vs. downtown residential) with emphasis on certain priority locations such as bus-stops, school zones, and high-volume routes (Ottawa and Toronto). Through the TMP, updates to sidewalk clearing can take the form of policy measures, but the City may also explore the possibility of using mapping to support connectivity and establish priority.

The benefits of establishing a priority system is that resources can be targeted where they are most effective, and citizens can have better knowledge regarding what to expect. The following list of considerations should frame the conversation around improvements to sidewalk clearing in the City:

- Differences between public vs. private clearing as City crews work and react with different priorities and frequency than private property owners
- AODA and accessibility, where there should be a commitment to clear and provide maintenance for all routes intended for winter use (sidewalks, pathways, trails)
- Definition of lower versus higher level of service, where priority routes receive the latter
- Using a mapping approach (akin to a winter priority cycling network map) can help to identify gaps and draw direct connectivity, but may be complex to visually present due to the broad range of factors that determine where sidewalks, pathways, and trails should be cleared

- A more typical policy approach can provide clear and consistent direction with more widespread coverage while managing the complexity of where clearance must occur and to what degree, but may not capture fine-grained connectivity between specific routes
- Pedestrians are likely to behave differently than cyclists in response to a priority map. Cyclists are able to make decisions more freely regarding their routes and divert with fewer consequences to travel time. Because of this, cyclists will prioritize routes that have been identified as higher quality in winter maintenance. Cyclists can also rely on cleared roadways as options to reach higher quality routes. In contrast, pedestrians cannot divert as quickly or use the roadways. The obstacles to reach prioritized routes may be insurmountable due to travel time and de-prioritized paths along the way which may be uncleared, unsafe, and inaccessible
- Developing a map or a policy will have implications for planning and warehousing and storage with regards to equipment, scheduling, and routes. Inclusion of routes and sections will need to be considered within the overall strategy. Complexity is increased where some routes require more time or resources (protected intersections, separated bikeways)

The building blocks of a sidewalk clearing policy can include the following:

- Locations/priorities through engagement
- ION Stations
- Mobility/accessibility
- Public destinations/institutions (community centres)
- Senior zones
- School zones
- High volume routes
- Downtown core
- Established practice
- Lighting availability
- Obstacles (stairways)
- Continuous connections
- Slip and fall data

Recommendation

The creation of a priority winter clearing network for cycling infrastructure should be a key objective of the update to the City's TMP. The details are to be determined through the update process including community engagement Phase 2. The analytics associated with this initiative will form the basis for route and strategy identification in a data driven approach. The process will also seek to formalize key spot improvements for winter clearing where there is an opportunity to create connections between local street bikeways and other pedestrian and bike priority streets.

Improvement of sidewalk clearing practices should also be a priority of the City's TMP due to clear public support from engagement and areas for improvement shown based on comparison to nearby cities. The City may consider improvements to overall policy to ensure widespread coverage and the inclusion of targeted areas (e.g. ION stations). A new policy can provide tiered levels of service based on factors listed above and determinants such as street type. A tiered level of service can help to manage allocation of resources and scheduling constraints. The City may also consider piloting the use of mapping a priority network to communicate resource allocation and/or achieve localized improvements to connectivity.

Successful implementation of any priority network or policy improvements will require monitoring and evaluation and may also need to be phased in over time as capacity grows or shifts to achieve the new service levels.

6.2 Other

Building on comparison to nearby cities, the City may consider the following additional recommendations to achieve goals of year-round sustainable transportation:

Policies and Practises

- Introducing pro-active approaches to anticipate conditions and applying preventative de-icing materials, as detailed in O. Reg. 239/02 for ice treatment of sidewalks and roadways. The North Dakota DOT reports that managing ice proactively uses one third as much de-icing material as reactive treatments
- Establishing policies that prevent, through design and pro-active response, and respond to ponding and ice formation in addition to snow removal for sidewalks and cycling routes
- Establishing policies for sweeping of gravel from cycling routes

Design

- Constructing bicycle lanes with adequate snow storage allocated through sufficient bike lane width, buffer space, or boulevard space
- Designing separated bicycle lanes at sidewalk level to simplify winter maintenance
- Ensuring adequate lighting for routes to provide safety and security in darker winter months, see **Planning for Future Cycling and Trail Routes** memo in this TMP for a review of illumination needs and priorities for off-road trails
- Considering winter access issues when designing gates and bollards

Communications and Programming

- Communicating plowing standards and status to the public (static and/or interactive)
- Targeting the creation of end-of-trip facilities that support winter active transportation (i.e., covered bike parking, enclosed bike parking, shower facilities or equipment storage, etc.)
- Developing programming to provide education and resources to the public on winter cycling

Figure 15: Raised Cycle Track (Ottawa)

Figure 16: Adawe Crossing - Example of snow pack standard for key new pedestrian/cycling bridge in Ottawa as part of Cross-Town Bikeway and Winter Priority Network

7 Impacts on Capital, Operating, and Maintenance Practices

As the City expands its network of sidewalks, trails, and cycling facilities, so do requirements and considerations for winter maintenance. With the introduction of new facilities comes impacts on capital, operating, and maintenance practices, particularly new complexity with regards to equipment, safety, cost, and accessibility. The Provincial Policy Statement (PPS) and Region of Waterloo Official Plan encourage optimization and fiscal responsibility, and long-term decision-making regarding winter maintenance should tie into the Long-Term Financial Plan and the Asset Management Plan, a component of which seeks to evaluate operating impacts of capital projects and new assets.

Capital, operating, and maintenance considerations due to winter clearance of active transportation facilities include:

- **Capital:** new/specialized equipment and impacts due to design-for-winter maintenance (recessed thermoplastic, buffer space, infrastructure such as bollards)
- **Operating:** staff and programming to manage maintenance and provide better delivery of services
- **Maintenance:** cost of clearing new infrastructure

The theme of capital, operating and maintenance considerations has been addressed throughout this document. To facilitate this discussion as the project moves into the next phase, examples have been provided based on facility type. The lists provided are not exhaustive but intend to help frame the discussion:

Scenario 1: On-Road Physically Separated Bikeway (physically-separated, at-grade with the roadway)

- Design
    - width
        - physical width of bikeway to allow a trackless vehicle to plow the bikeway portion (note: not at grade with the sidewalk)
        - snow storage
    - option for bollards mounted on pinned curbs or cast-in-place curbs
        - if bollards mounted in asphalt then impact on design if removed in winter
    - ponding
- Durability
    - green thermoplast
    - pavement markings
    - wearability of material selection for physical separation (i.e., pinned curbs or cast-in-place curbs)
    - bollards (mounted in asphalt or on curbs)
- Operating
    - snowing clearing (routing, staffing, equipment)
        - note: bikeway not at the same grade as the sidewalk
        - note: example of jurisdictional issue is at transit stops
        - additional resources required when pedestrian refuge islands are included in the design
    - snow storage
    - ice accumulation
    - debris removal

    - if removing bollards in the winter and reinstalling/replacing post winter then operating impact (i.e., removing/replacing, storing and sourcing)
    - if planters are used in design then operating impact (watering, plantings, potential removing in winter, storing and sourcing)

Scenario 2: Raised Cycle Track (physically-separated, at-grade with the sidewalk)

- Design
    - width
        - physical width of bikeway to allow trackless vehicle to plow bikeway portion (note: at grade with the sidewalk facilitating multiple passes)
        - snow storage
    - less need for bollards (i.e., vertical separation through use of curb)
    - less likely to be ponding issues midblock (potential where raised cycle track drops to transition to adjacent facilities)
    - increased utility conflicts as more likely adjacent to utility poles
        - for example: utility poles between cycle track and roadway or between cycle track and adjacent sidewalk
    - treatment of raised cycle track at private driveways/entrances
- Durability
    - green thermoplast
    - pavement markings
        - less motor vehicle traffic over portion of the required pavement markings
    - concrete curb subject to typical wear adjacent to roadway but with introduction of vertical element of raised cycle track, less reliance on wearability of the curb related to a raised cycle track
- Operating
    - snowing clearing (routing, staffing, equipment)
        - note: bikeway at the same grade as the sidewalk
        - note: example of jurisdictional issue is at transit stops
        - potential for increased snow and ice accumulation as less motor vehicle interaction with the surface when raised cycle track
        - additional resources required when pedestrian refuge islands are included in the design
    - snow storage
    - ice accumulation
    - debris removal
    - if planters are used in design then operating impact (watering, plantings, storing and sourcing)

Scenario 3: Trails

- Design
    - multi-use pathway versus separated cycling and pedestrian spaces
    - subbase and surface type have an impact on equipment options
    - ponding
    - gates
    - intersection and crossing treatments
    - lighting

    - signage indicating if to be winter maintained
- Durability
    - surface material selection
    - green thermoplastic
    - surface trail markers
- Operating
    - snow clearing (routing, staffing, equipment)
    - increased trail width has an impact on equipment options
    - gates and access
    - ice accumulation
    - debris removal

8 Benefits Statement

Investment into winter maintenance of bikeways and pedestrian facilities removes barriers to walking, riding bikes, and taking transit in winter months by improving safety, accessibility, and comfort with the benefit of increasing mode share for sustainable modes of transportation.

The following is a quick reference list of the benefits of winter maintenance for active transportation:

- Winter maintenance improves mode share of walking and biking in the winter
- Investment in quality snow clearing of walking and cycling facilities supports conventional transit and the new ION system
- Improving bike and cycling accessibility in winter releases latent demand and changes the flawed perception that "no one bikes in the winter"
- Winter maintenance extends the usability of a constructed facility for a greater portion of the year
- An existing on-road bike lane, as an example, does not automatically close in the winter months and activities such as winter maintenance improve the safety of such a facility
- A changing "winter season" and weather cycles allow for cycling without snow or ice year-round
- Regular winter maintenance improves shoulder-season cycling by reducing lingering frozen debris
- The same equipment typically used to clear snow from roads and sidewalks can sometimes also be used for cycling facilities depending on width and separator treatments
- Improved winter maintenance is a benefit to all roadway users who require safe access to transit, work, retail, friends and family, and society, not a niche group of winter cyclists or walkers
- Winter maintenance extends mobility and safety to groups particularly affected by icy and snowy conditions such as seniors and people with physical and/or mental disabilities
- Personal health through daily exercise
- Provides 'eyes on the street' year-round

9 Conclusion

The City has been taking steps to improve winter maintenance practices for active transportation facilities. It is now faced with the question of how to move it further and where to focus its efforts to maximize benefits. Policies for winter maintenance impact whether people choose to ride bikes or walk in the winter months, affecting access to transit, accessibility for vulnerable users, and safety, all of which must be considered to create an all ages and abilities network. In developing future winter maintenance practices, the City will need to fully incorporate existing minimum standards while looking to nearby municipalities and guidance documents for best practices, and evaluating how to address internal challenges. This memo provides a framework for decision making with a summary of current standards, nearby cities, existing practice, challenges, stakeholder engagement, and impacts on operating, maintenance, and capital costs, and discusses recommendations to consider.

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[1] Toole Design, Winter Maintenance Resource Guide, Dec 2019

[2] Region of Waterloo. *Separated Cycling Lanes*. Retrieved from: https://www.regionofwaterloo.ca/en/exploring-the-region/separated-cycling-lanes.aspx

[3] City of Kingston. (2019). *Winter Maintenance Policy* (Report No. EITP-10-010). Retrieved from: https://www.cityofkingston.ca/documents/10180/37095404/Environment-Infrastructure-Transportation-Policies-Committee_Meeting-05-2019_Report-EITP-19-010_Winter-Maintenance-Policy.pdf/c93eb2b7-06f5-462f-8e8f-de3327c4cc27

[4] City of Cambridge. (2019). *Winter Control Optimization.* Retrieved from: https://www.cambridge.ca/en/your-city/resources/Cambridge-Winter-Final-Report.pdf

[5] City of Waterloo. *Snow Removal.* Retrieved from: https://www.waterloo.ca/en/living/snow-removal.aspx

19 PHASE TWO POLICY AND TECHNICAL SUMMARY

TRANSPORTATION MASTER PLAN
LOOKING AHEAD

THE CITY OF Waterloo

Summary Report

Date: August 13, 2020

To: Christopher Hodgson, City of Waterloo

From: Gene Chartier, Paradigm Transportation Solutions Limited

c.c.: Kate Whitfield, Alta Planning + Design
Susan Hall, Lura Consulting

Re: **Phase Two Policy and Technical Summary**

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1 Introduction

This report summarizes the policy and technical analysis carried out during Phase Two of the **City of Waterloo Transportation Master Plan Update (WTMP)**. The document is organized as follows:

- Chapter 2 outlines the vision statement and goals for the WTMP;
- Chapter 3 describes the alternative planning strategies and evaluation;
- Chapter 4 summarizes the guiding principles and philosophies policy directions; and
- Chapter 5 details the active transportation recommendations.

2 Vision Statement and Goals

Much has changed over the past nine years since City Council adopted the 2011 TMP. The recently released 2018 Region of Waterloo Transportation Master Plan and the City's 2019-2022 Strategic Plan focus not only on mode choice but also **equity, inclusion, sustainability, community health, safety, growth, and prosperity**. Travel modes other than the auto will not just be considered "alternatives" but will represent viable transportation options for daily use. Residents and visitors to the City will have the option to travel safely and efficiently within and through Waterloo using their mode of choice regardless of age or abilities. Communities and transportation systems will be developed and maintained with sustainability and healthy living in mind. Existing resources will be used more efficiently or repurposed. A holistic approach to managing the transportation system will allow the City to continue to grow and prosper to 2041 and beyond.

With these objectives in mind, the transportation vision for the WTMP is as follows:

Waterloo has an equitable transportation system built on the principles of sustainability, choice, and safety.

The vision is supported by the following four goals:

- **Promote Travel Choice** – All individuals who live, work, visit or undertake recreational activities within the City can make trips in an integrated and seamless manner without having to drive (or own) a car. By achieving transportation equity, different travel modes, including walking, cycling, and public transit, are competitive in terms of travel time, cost, and accessibility.
- **Create a Sense of Belonging** – Transportation services provide access to equal opportunity and benefits for all citizens. Treating everyone equitably requires an acknowledgement of the unique circumstances different individuals face and provides the basis to eliminate systemic barriers. This helps to support overall neighbourhood livability, enhance quality of life, and build a strong sense of community through primarily active transportation services.
- **Support Sustainable Development** – The transportation system supports sustainable growth initiatives within the City, benefiting both the economy and environment. Enabling sustainable development patterns helps to reduce transportation contributions to climate change.
- **Optimize the Transportation System** – Make the most of infrastructure and services that already exist. Managing transportation supply and demand will help to maximize the use of existing facilities and defer the need for new infrastructure that does not support the other goals.

3 Alternative Planning Strategies

The Municipal Class Environmental Assessment process requires documentation and examination of all reasonable alternatives to address the problems and opportunities and achieve the transportation vision. Consistent with the 2011 TMP, the alternative planning strategies are defined as follows:

Alternative 1: Capacity Focus Strategy	A long-term transportation strategy that continues to provide roadway network capacity in response to growing traffic demands could be considered a “business as usual” approach. This is because the capacity focus would continue to add vehicle travel lanes and extend roads to primarily accommodate motorized traffic, often at the expense of the expansion and improvement to the active transportation infrastructure and services. It would also perpetuate auto use and compete successfully against transit ridership growth.
Alternative 2: Demand Focused Strategy	A long-term transportation strategy that is demand-focused would concentrate on changing travel characteristics in the movement of people and goods within and through the City. At its extreme, a demand-focused strategy could strategically withhold roadway capacity enhancements to create the functional incentives needed to shift travel demands towards transit and active transportation.
Alternative 3: Complete Transportation Strategy	A long-term transportation strategy that is complete aims to decrease the growth in private auto use and increase the use of alternative modes. Private auto use would still be the predominant mode of transportation, but a complete strategy would reduce the amount of road construction needed to serve future travel demands, provide added incentives to optimize the carrying capacity of the roadway network and provide new opportunities to strategically convert or adjust the auto carrying capacity of selected City streets towards alternative transportation and/or streetscape uses.

A multiple account evaluation (MAE) framework was developed to assess the three alternatives. The evaluation criteria used in the assessment included factors related to transportation, natural, social and policy environments, and economic implications. Each criterion was assigned a score between 1 (least preferred) and 5 (most preferred) with the alternatives ranked based on total score. **Figure 1** summarizes the results.

Alternative Planning Strategy	Transportation	Natural Environment	Social Environment	Policy Environment	Economic	OVERALL RANK
Alternative 1 Capacity Focused Strategy						**3**
Alternative 2 Demand Focused Strategy						**2**
Alternative 3 Complete Transportation Strategy						**1**

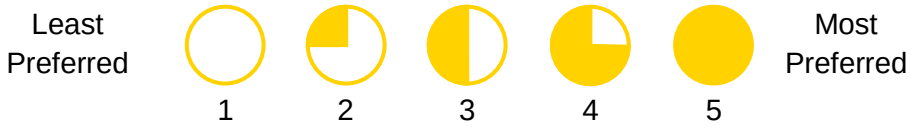

Figure 1: Multiple Account Evaluation of Alternative Planning Strategies

The MAE assessment led to the selection of **Alternative 3: Complete Transportation Strategy** as the preferred planning approach for the WTMP. Advancing a strategy focused on all modes of travel while optimizing the City's existing infrastructure reflects the vision of an equitable transportation system built on the principles of sustainability, choice, and safety. A sensitivity analysis confirmed the preferred alternative remained the same regardless of the weight assigned to the criteria.

4 Guiding Principles and Philosophies

4.1 Complete Streets

Complete Streets is a broad policy approach typically defined as streets for everyone, purposely designed and operated to allow for safe access for all users. The Complete Streets vision is one of

leveraging the potential for streets to support a variety of uses and a more diverse mode share with focus areas of safety, health, multi-mobility, transit, accessibility, sustainability, and equity. For the City, Complete Streets policies aim to achieve the goal of being “economically viable, sustainable, vibrant, walkable, bicycle friendly, age friendly, accessible, and diverse”. While high-level in concept, a Complete Streets policy should translate to implementation strategies that alter regular decision-making in planning, design, construction, operation, and maintenance.

The Complete Streets approach is not new. The 2011 TMP included an overarching Complete Streets Policy for all streets to be planned, designed, operated, and maintained to enable safe access for all users, only the second municipality in Canada to adopt such a policy. But the approach is evolving in response to new transport modes, on-demand mobility services, and rapid integration of technology. Complete Streets 2.0 responds to this new reality, where the core principles remain the same, but the actions reflect a changing context for planning, design, maintenance, and operations. A variety of new ideas and design approaches, including mobility hubs, curbside management and micromobility, are under review and being implemented in various municipalities.

Recommendations

Incorporating Complete Streets 2.0

An updated Complete Streets policy approach and corresponding set of tools will assist the City in achieving its defined vision. **Figure 2** summarizes the principles of Complete Streets 2.0, which include prioritizing uses on the street, recognizing new modes, and incorporating flexibility.

Figure 2: Complete Streets 2.0 Principles

With the new tools and policy approaches, the City should prioritize:

- Allocating space to serve specific objectives defined by mode and demand while managing safety;
- Measuring the right outcomes, for example where person-throughput is prioritized over vehicle-throughput;
- Using interim treatments and pilot projects/demonstration projects as alternatives to major capital projects to test ideas and move forward on implementation;
- Implementing mobility hubs through policies and permitting to support shared mobility services, bike parking, drop-off zones, etc.; and
- Designing for flexibility and changing time of day or seasonal uses.

Tools for Implementation of Complete Streets

A comprehensive Complete Streets policy will identify and develop tools to address typical challenges that stall projects. Tools help with managing trade-offs and design decision-making particularly in constrained spaces. When properly created, processes and tools can be structured to ensure appropriate attention is paid to factors that may historically not receive due consideration, such as equity, green infrastructure, and street trees/urban forestry. The City should consider existing tools developed by comparable cites for implementing Complete Streets 2.0, including:

- City of London CDSM Toolkit;
- City of Kitchener Score Cards;
- City of Ottawa Multimodal Level of Service (MMLOS) Framework; and
- City of Toronto Curb Radii Guidelines.

Vehicle Travel Lane Widths

Decisions regarding lane configuration and widths represent a conscious allocation of space that has implications for the use and function of a roadway including vehicles types and modes, crossing distances, and parking availability. Altering lane widths can be a tool to effectively use a limited right-of-way while achieving Vision Zero and Complete Streets policy goals to prioritize safety for vulnerable users and design for all modes. This tool, coupled with an understanding of best practices and the relationship between lane widths, speed, capacity, and safety, can be used to design a street for all users, but also to fit its context within the overall road network.

The City of Waterloo Engineering Manual provides standard cross-sections for different roadway classifications and configurations. The current cross-sections, which were published in 2005, cite standard lane widths of:

- Two-lane road, no median: 3.7 metre lanes, 1.5 metre bike lane
- Two-lane road with 3.0 metre median: 4.2 metre lanes, 1.5 metre bike lane
- Four-lane road with 5.0 metre median: 3.65 metre lanes, 1.5 metre bike lane

Several recent City road reconstruction projects have deviated from these standards, using lane widths as narrow as 3.25 metres on major collector roadways.

A review of best practice completed for the WTMP suggests the lane widths used in City standard cross-sections are overly wide. Wide lane widths encourage speeding, diminishes safety for pedestrian and cyclists, and result in longer pedestrian crossing distances at intersections. It also restricts space for other needs in the right-of-way such as trees, boulevards, and utilities. Wider than necessary lanes may also lead to higher spending on road construction and maintenance for the City, especially as efforts to incorporate more travel modes become more prominent.

To be consistent with best practices and comparable cities, the City should consider narrowing lane width requirements and reducing roadway cross-sections in three ways:

- **Remove Centre Medians** – Consider an alternative cross-section without a centre median where the context is appropriate with regards to land use, traffic, and other variables. This provides additional boulevard space for active transportation facilities and landscaping, plus reduces crossing distances for pedestrians at intersections.

- **Avoid Lanes Wider than 3.5 Metres** – Eliminate general purpose vehicle lanes wider than 3.5 metres in urban conditions as they promote faster speeds and consume greater amounts of right-of-way. For existing roadway cross-sections, consider visual narrowing through pavement markings by:
    - Adding a longitudinal white stripe 0.3 metres from the curb or at the edge of the gutter when the vehicle lane is adjacent to the curb; and
    - Narrowing the vehicle lane and using the excess width to create a painted buffer between when the vehicle lane is adjacent to a bicycle lane.
- **Narrow Curb Lanes in Conjunction with Buffered Bicycle Lanes** – Reduce lane widths on streets with separated bicycle lanes at the curbs. The buffer zone can provide additional width for larger vehicles. Narrow curb lanes with a buffer promote slower vehicle speeds and provide greater horizontal separation between vehicles and cyclists compared to a wide curb lane and a conventional bike lane. The buffer space may be painted and/or include features such as bollards or planters.

Complete Streets Policy Communications

Several municipalities have improved communication strategies to bring increased public engagement to Complete Streets implementation. Including additional communications tools corresponds directly to the communication pillar of the City's current Complete Streets policy. The City should adopt/adapt communications practices that can frame similar initiatives in Waterloo including:

- City of London's Citizen's Guide to Complete Streets;
- City of Kitchener Community Guide to Complete Streets; and
- City of Ottawa MMLOS Framework.

Strengthening the Policy Framework

To align future Complete Streets policies with best practice, the City should track defined metrics created by the National Complete Streets Coalition of Smart Growth America for the following elements:

- Vision and intent
- Diverse users
- Commitment in all projects and phases
- Clear, accountable expectations
- Jurisdiction
- Design
- Land use and context sensitivity
- Performance measures
- Project selection criteria
- Implementation steps

4.2 Vision Zero

Vision Zero is a strategy to eliminate traffic fatalities and severe injuries, while increasing safe, healthy, equitable mobility for all. Originating in Sweden in the late 1990's, Vision Zero is based on the philosophy that:

- No loss of life is acceptable;
- Traffic fatalities and serious injuries are preventable;
- People make mistakes so the road system and related policies should be designed to ensure those inevitable lapses do not result in severe injuries or fatalities; and
- Humans are physically vulnerable when involved in motor vehicle collisions.

Vision Zero starts with the ethical belief that everyone has the right to move safely in their communities. The concept deviates from the traditional view of road safety in two primary ways:

1. System designers and policymakers share responsibility for ensuring safe travel with road users and are expected to improve the roadway environment, policies (such as speed management), and other related systems to lessen the severity of collisions; and
2. Addressing this complex problem requires a multidisciplinary, collaborative approach, bringing together diverse stakeholders such as traffic planners and engineers, enforcement personnel, policymakers, public health professionals, and decision makers.

Typical focus areas for Vision Zero initiatives include:

- Positioning road safety as a top priority in policymaking;
- Improving road infrastructure for all road users;
- Enhancing the safety of vulnerable road users;
- Increasing enforcement of laws to manage safe speeds and reduce impaired and distracted driving;
- Strictly regulating and testing vehicles;
- Leveraging innovative technology (red light cameras, automated speed enforcement); and
- Continuing leadership, collaboration, and accountability among all stakeholders.

Key activities to ensure Vision Zero becomes a reality include:

- Road infrastructure changes;
- Enhanced regulation and enforcement;
- Advocacy for policy change; and
- Raising public awareness and commitment to road safety.

Current City traffic safety programs are based on the same philosophy as Vision Zero and offer the same breadth of perspective, in that the City incorporates education, enforcement, engineering, evaluation, and engagement in its initiatives. From a safety perspective, the City's road network appears to performing better than others in Canada and even in Sweden based on research completed by the Region of Waterloo. But the City is always striving for improvement, particularly as there is a renewed emphasis on increasing mobility by active transportation and transit.

Recommendations

Road Safety Policy and Action Plan

Fatalities and serious injuries are unacceptable outcomes of motor vehicle collisions. But formally committing to Vision Zero presents several important factors and potential consequences for the City to consider. Making this commitment would likely require considerable investment in infrastructure changes and/or electronic enforcement to compel drivers to further reduce vehicle speeds and comply with other traffic rules (e.g., stop sign and red light running). Experience has shown signs and markings alone have limited long term effect. On the other hand, physical measures can adversely impact emergency response (fire, ambulance, and police) and transit service delivery. As well, the design and operation of the road is only one factor contributing to traffic-related fatalities and serious injuries. Driver behaviour and the vehicle, factors largely outside the City's control, also play a critical role.

City Council has expressed a strong desire in committing to Vision Zero as evidenced by its stated objectives in the *City of Waterloo 2019-2022 Strategic Plan*. Consistent with this direction, the City should articulate a formal policy on road safety that pledges to Vision Zero and captures the key tenets of this strategy. This policy could read:

> *As a Vision Zero community, the City of Waterloo, with the support of its partners, aims to eliminate traffic-related fatalities and serious injuries on City roads using a Safe Systems Approach consistent with its Complete Streets Policy.*

Along with adopting this policy, the City should develop a Road Safety Action Plan (RSAP), consolidating its traffic safety-related initiatives into one comprehensive strategy with clear objectives, stated outcomes, and required funding. The RSAP should follow the Safe Systems Approach, implementing evidence-based measures for safe drivers, safe speeds, safe roads, and safe vehicles.

The City should also pursue new methods of identifying locations and trends with potential for safety improvement (consistent with the recommendations of the TMP Update memorandum "Addressing Identified Collision Locations") and implement proven countermeasures. Additionally, the City should consider trial applications of emerging countermeasures on a site-specific basis to evaluate their potential benefit in Waterloo. The availability of new technology, such as automated and connected vehicles, may also have a positive influence on the future of road safety.

Neighbourhood Speed Limits

Reducing speeds is key to achieving an improvement in road safety, especially for vulnerable road users like pedestrians and cyclists. The risk of serious injury or fatality for a pedestrian involved in a collision with a motor vehicle increases considerably as speeds climb.

Area-wide speed limit reductions are not common in Ontario municipalities comparable to Waterloo yet although several are currently considering this approach. Even where a jurisdiction has taken this approach, analysis findings are not yet available, making it difficult to reliably assess the merit of implementing such measures in Waterloo. From the City's experience in reducing speed limits in school zones, follow-up field surveys indicate speeds tend to diminish but remain above the 40 km/h posted limit. Sufficient data was not available to assess the sustained, long-term effects of these lower speed limits.

Consistent with its philosophy on Vision Zero, City Council has expressed a strong desire to realize lower vehicle speeds in the City, specifically for safety reasons on neighbourhood streets and especially around schools. But as previously noted, installing signs alone rarely achieves compliance with lower posted limits and sustained long-term change in vehicle operating speeds. For this reason, the City should develop a comprehensive Speed Management Program in concert with a policy of area-wide 40 km/h speed limits on neighbourhood streets and 30 km/h speed limits in school zones. Building on the City's current pilot in the Westvale and Eastbridge neighbourhoods, the program should focus primarily on speed management for local and collector roads within its residential communities. Most higher order roads in the City fall under the jurisdiction of the Region of Waterloo or Ministry of Transportation, with the few remaining arterial facilities under City control intended to facilitate the movement of large volumes of people, including truck traffic, at higher speeds.

Addressing Identified Collision Locations

As part of a broader strategy aligned with Vision Zero principles, the City should pursue a more formal data-driven, evidence-based decision-making process for its road safety program. A data-focussed program will help City Council, citizens and other interested parties better understand the nature, causes, and injury outcomes of collisions, providing context for the design of strategies and interventions that will reduce crashes and their adverse consequences.

The program should incorporate the two approaches to safety management, being the selection and treatment of sites based on:

- Site-specific collisions (collision-based); and
- Site-specific geometric and operational attributes known to increase collision risk (systemic).

The collision-based and systemic approaches are complementary and support a comprehensive approach to safety management, with their primary difference being the way in which the agency identifies issues and develops projects. The systemic approach is more preventative in nature, applying countermeasures to locations with features correlated with collisions but not necessarily having a history of crashes. This distinction is important because the types of collisions occurring on a system remain relatively consistent from year to year while their locations tend to fluctuate, particularly on lower volume roads. It is difficult to address these sites with the collision-based approach due to the low density of crashes and typical data limitations associated with local roads. The systemic approach helps to overcome these limitations by focussing on the underlying risk factors across the network as opposed to collision history at individual locations. While there are differences in application, both approaches focus on preventing future collisions and reducing fatalities and injuries.

This data-driven **road safety management** (RSM) process will provide the City with valuable information for system planning, project planning, design and construction, and operations and maintenance of its road network. Safety evaluation develops the evidence-based information used in the RSM process, which can be integrated into the overall project development process.

4.3 Emerging Technologies

The transportation sector is witnessing significant changes in the technologies used and attitudes towards moving people and goods. Municipalities need to develop appropriate responses to these

emerging trends, adapting and evolving current transportation and land use planning policies and practices to position their communities to be ready for and (hopefully) benefit from this transformational and disruptive shift in mobility services.

Increased environmental awareness, advancements in technology, rising life expectancies, households working longer, and Millennials entering the workforce are contributing to fundamental changes impacting mobility. These changes are contributing to five converging mobility innovations:

- **Shared Mobility**: Shared mobility enables users to gain short-term access to transportation modes on an "as-needed" basis. The ecosystem of shared services continues to grow and includes an array of services, such as car sharing, microtransit, shared micromobility (e.g., bike sharing and e-scooter sharing), transportation network companies, and public transportation;
- **Digital information and Fare Payment Integration**: These services can help bridge information gaps, make multimodal travel and public transit more convenient, and enhance decision-making with dynamic and real-time information throughout an entire journey;
- **The Commodification of Transportation**: Consumers are assigning economic values to travel modes and engaging in multimodal decision-making processes based on a variety of factors such as cost, journey time, wait time, number of connections, and convenience. Rather than making decisions between modes, mobility consumers can make decisions across modes, in essence "modal chaining" to optimize the route, travel time, and cost;
- **Automation**: Vehicle automation also has the potential to create new and exciting opportunities for both the public and private sectors, such as cost savings; automated pick-up, drop-off, and charging; and more economical and convenient demand-responsive services; and
- **Electrification**: Electric vehicles that use one or more electric or traction motors for propulsion can reduce GHGs and other emissions, mitigating many of the transportation-related impacts associated with increased urbanization in cities.

Through the WTMP, the City can help establish the principles and key components of its response to emerging technologies and trends in transportation and provide the foundation for further research and action.

Recommendations

Shared Mobility

In the field of shared mobility, the City should:

- Undertake a phased approach to adopting bike, car, and other modal (e.g. scooter) sharing opportunities;
- Assess the potential for a Mobility as a Service (MaaS) system;
- Develop a curb management strategy for meeting competing demands on curb space; and
- Explore the development of an Ecomobility Hub in the Uptown area.

Automated, Connected and Electric Vehicles

In response to the evolving development of automated, connected, and electric (ACE) vehicles, the City should:

- Permit the testing of low-speed automated vehicles;
- Continue to establish publicly accessible vehicle charging infrastructure;
- Continue to transition the city's fleet of vehicles towards electric and low carbon fuels;
- Explore car parking reform, including real time information and dynamic pricing; and
- Develop planning strategies for the eventual repurposing of unneeded transportation infrastructure, parking lots, and roadside parking spaces.

Smart Cities

Recognizing potential transportation opportunities associated with "big data" and technology that leverages the information, the City should:

- Make City assets and information available (e.g., open data) for use to facilitate technological development; and
- Consider developing a Smart City strategy.

Supporting Initiatives

To support efforts and respond to trends, the City should:

- Continue to monitor and research emerging transportation technologies and the impacts of new mobility trends;
- Collaborate with universities, private industry, and all levels of government on various initiatives and pilot projects;
- Conduct public education campaign to communicate the benefits of new mobility models;
- Build knowledge through staff attendance at key meetings and conferences;
- Explore opportunities for participation in funding programs; and
- Develop/align city regulations, permits, and policies for new mobility.

5 Active Transportation

The WTMP primarily focusses on improvements to active transportation in the City. Developing the strategy involved consideration of existing cycling and pedestrian networks, current travel demands and collision history, gaps in the network, and network connectivity in terms of access to transit, schools, and other community destinations.

The following summarizes the key active transportation directions and recommendations of the plan.

5.1 Planning and Design

Pedestrian Network

The City should address plans for sidewalks and walkways through policy, building on the its current framework and priority program. The pedestrian network will be enhanced through the network development work being completed in the proposed ultimate cycling network, as it will help the City to clarify existing trail standards and add trail connections to provide low-stress and direct routes for pedestrians.

Cycling Network

The City should continue to improve and expand its cycling network, leveraging past investments to future benefit. The ultimate cycling network shows existing and proposed facilities to form the future cycling network. The ultimate network resolves many of the gaps identified in the Network Gap Analysis and is classified into four on-road classifications:

- Physically Separated Bikeways
- Visually Separated Bikeways
- Neighbourhood Bikeways
- Conceptual Connections

The network was developed through a comprehensive, data-driven process involving analytical assessment and thorough review. The network aims to eliminate missing links and provide continuity for cycling within the City. Consultation with the Waterloo Active Transportation Advisory Committee (WACAT) and input from the public helped shape and confirm the routes.

The ultimate cycling network also shows the existing trail network, which has been reclassified to identify trails that provide a transportation purpose based on alignment and connection and taking into consideration existing surface material.

The primary network is the backbone of the cycling system and consists of important cross-town routes providing access to major destinations (such as Uptown, the universities, and ION stations). These routes should be prioritized for maintenance, snow clearing, road crossing upgrades, among other elements.

The proposed projects from the ultimate cycling network will be implemented over time, either as standalone capital projects or as part of road renewal and reconstruction works. A prioritization process was developed to rank initiatives based on measurable criteria related to goals of the project (quantitative approach) and opportunity to implement the facility (qualitative approach). The process is intended to be iterative and flexible, recognizing priorities may change over time as new information emerges or other opportunities arise. In some circumstances, the City should consider implementing lower cost options in the short-term and then update/upgrade the facility as part of a future capital works project.

The schedule of unit costs for implementing cycling infrastructure was also updated to reflect prevailing conditions. Costs were provided for both capital and retrofit projects where relevant. Not surprisingly, the updated facility costs represent an increase from the values cited in the 2011 TMP. The City should use these figures in high-level planning.

Regional roads are shown for context as either existing or planned facilities based on the 2018 Regional Transportation Master Plan. No changes to the facilities on Regional roads have been proposed although there may be an opportunity for the City to work with the Region to propose new facility classifications for Regional roads. For the priority network, Regional roads are used in isolated cases where they provide an important linkage in the overall network.

Intersections and Crossings

Design concepts of intersection and crossings were developed for five locations in the City to present potential and conceptual ultimate reconstruction conditions and illustrate design and engineering principles and best practices. The widths and geometries of the roadway elements are based on standard dimensions from Ontario Traffic Manual Book 18: Cycling Facilities (2013).

In addition, the WTMP includes a summary of short and long-term intersection and crossing countermeasures that benefit cycling and walking. The short-term countermeasures are intended to be low-cost and easy to implement, while the longer-term measures are to be considered when improvement opportunities arise through reconstruction. The City should move forward with these initiatives to improve safety and continuity of the active transportation network.

Highway 85 Crossings

As part of the network development process, potential locations for new active transportation crossings of Highway 85 were reviewed, with the goal of facilitating safer and more direct active transportation access. Potential north (between Northfield Drive West and King Street North) and south (between University Avenue East and Bridgeport Road East) crossings were identified. The grade separated crossings should be designed with a focus on user experience, such as direct access, ample width for passing others, limited slope, geometry that allows for people to comfortably ride and make turns, as well as lighting. The City should proceed with a more detailed investigation and Class Environmental Assessment for these two crossing options.

Trail Lighting

Lighting plays an important role in both the actual and perceived sense of safety and security for trail users. Properly designed lighting increases visibility and helps to prevent collisions with other users or objects such as bollards. Lighting is especially important on trails that are used primarily for transportation purposes as these facilities often provide direct connections to key destinations frequented outside of daylight hours. Users commonly request lit trails during public engagement events, including the engagement activities carried out for the WTMP.

The City should develop a trail lighting policy based on facility type and considering scenarios where illumination may be appropriate. Transportation focused trails should be the priority for lighting. Other trails have a more recreational focus and lighting could impact the experience of the trail and/or the surrounding environment. Trails for lighting should be prioritized in sizeable sections so that projects can provide a more significant benefit instead of just a spot improvement.

Wayfinding and Signed Routes

Wayfinding is a system of signs, markings, maps, and other signifiers by which people follow a route from one place to another. It is intended to help individuals navigate their surroundings intuitively and efficiently. A robust wayfinding system can benefit active transportation, including assisting with orientation, route planning, promotion and placemaking in the City.

The City's existing wayfinding system follows NACTO guidelines. This includes use of a hierarchy of destinations, including distances and time to destinations, and sign types that differ by function. Some of the major trails include the trail name and logo, as well as the characteristics (trail length, surface material, width, slope, and amenities) consistent with *Accessibility for Ontarians with Disabilities Act*

(AODA) requirements. The City also provides signs identifying trails not maintained in winter. Currently, the wayfinding system is limited to the High Priority Trail Network but is gradually expanding to other on- and off-road routes.

Although the existing wayfinding system already meets most recommended design guidelines, the City should enhance the program by:

- Including turn signs at junctions plus other optional types, such as trail head signs, at major junctions or congregation points;
- Installing signs meeting the standards set out in the AODA for new and rebuilt recreational trails. Additional accessibility information is required on signs at the start of the recreational trail;
- Developing a standard sign template for use at the start of all recreational trails;
- Maintaining the existing GIS database and inventory of wayfinding signs;
- Considering impacts of construction projects on active transportation infrastructure and providing suitable, signed detour routes;
- Integrating the City's wayfinding system with Region of Waterloo, City of Kitchener, and Grand River Transit signing, including use of consistent sign types, designs, and corresponding destinations;
- Mitigating and avoiding over signing and sign "clutter" in the public realm through supplementary pavement markings, increased coordination with other departments and jurisdictions, and other strategies; and
- Expanding the program to include other parts of the active transportation network.

5.2 Operations and Maintenance

Investing in winter maintenance of bikeways and pedestrian facilities helps remove barriers to walking, cycling, and taking transit in winter months. Enhanced snow clearing, snow removal, and ice treatment improves safety, accessibility, and comfort with the benefit of increasing the use of sustainable travel modes. But as the City expands its network of sidewalks, trails, and cycling facilities, requirements and considerations for winter maintenance also grow.

Currently, the City, at a minimum, maintains active transportation facilities according to the standards set out in with Ontario Regulation (O. Reg.) 239/02 under the *Municipal Act, 2001* (the Minimum Maintenance Standards) including maintenance of all regional roads on behalf of the Region of Waterloo. The City also provides service alerts related to snow-related parking bans.

The WTMP provides the policy foundation for an enhanced winter maintenance program for the priority network and offers guidance on other improvements to improve the ease, convenience, and safety of overall active travel throughout the year.

The City should introduce sidewalk and cycling network specific winter maintenance practices that exceed the minimum requirements specified in O. Reg. 239/02 in many circumstances including:

- Developing a priority winter clearing network for cycling infrastructure based on key routes and connections;
- Formalizing key locations for spot improvements where there is an opportunity to create connections between local street bikeways and other pedestrian and bike priority streets;

- Improving sidewalk clearing practices to ensure widespread coverage and the inclusion of targeted areas (e.g. ION stations). The new policy can provide tiered levels of service based on factors and determinants and can help manage allocation of resources and scheduling constraints;
- Considering piloting the use of mapping a priority network to communicate resource allocation and/or achieve localized improvements to connectivity; and
- Implementing a monitoring and evaluation program phase in winter maintenance improvements over time as capacity grows or shifts to achieve the new service levels, and to ensure winter maintenance is acceptable to users.

The City may consider the following additional recommendations to achieve goals of year-round sustainable transportation:

- Introduce a pro-active approach to anticipate conditions and apply preventative de-icing materials, as detailed in O. Reg. 239/02 for ice treatment of sidewalks and roadways;
- Establish policies that prevent, through design and pro-active response, and respond to ponding and ice formation in addition to snow removal for sidewalks and cycling routes;
- Establish policies for sweeping of gravel from cycling routes;
- Construct bicycle lanes with adequate snow storage allocated through sufficient bike lane width, buffer space, or boulevard space;
- Design separated bicycle lanes at sidewalk level to simplify winter maintenance;
- Ensure adequate lighting for routes to provide safety and security in darker winter months;
- Consider winter access issues when designing gates and bollards;
- Communicate plowing standards and status to the public (static and/or interactive);
- Target the creation of end-of-trip facilities that support winter active transportation (i.e., covered bike parking, enclosed bike parking, shower facilities or equipment storage, etc.); and
- Develop programming to provide education and resources to the public on winter cycling.