

2020

# TRANSPORTATION DESIGN MANUAL

ENGINEERING DEPARTMENT



## FOREWORD

This manual was prepared by GHD, in collaboration with the City of Barrie (City) under the direction of a Technical Working Group consisting of subject matter experts from following City departments/units:

- Policy and Standards, Engineering
- Infrastructure Planning, Engineering
- Development Services, Engineering
- Design and Construction, Engineering
- Technical Operations, Roads, Parks and Fleet
- Traffic and Parking, Roads Parks and Fleet
- Accessibility, Human Resources

This manual was developed to reflect current and emerging standards and technology, legislation and best practices as they exist in 2017. The manual also considers corporate initiatives such as the [2014 Multi-Modal Active Transportation Master Plan \(MMATMP\)](#) and the [2015 Corporate Asset Management Plan \(AMP\)](#). It should be recognized that this manual cannot provide direction for all circumstances encountered. The City reserves the right to apply discretion in the interpretation of this manual and require the use of other applicable guidelines and good engineering judgement when reviewing each project.

The design of all municipal services in the City is to be based upon the specifications and standards in effect at the time of submission. It is incumbent upon the designer to ensure that the latest specifications are being utilized. All plans are to be accepted by the City before they are used for the construction of municipal infrastructure; however, such acceptance in no way relieves the designer from providing an adequate and safe design. Current legislation shall be followed at all times.



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## 1 Introduction

The purpose of this manual is to provide guidance to designers, developers, and contractors for the design and installation of road infrastructure systems within the City of Barrie. This manual and associated standards shall not relieve the proponent from the primary responsibility for the design to meet applicable federal, provincial and municipal regulations.

This manual provides best-practice sustainable transportation standards to support the [2014-2018 Council Strategic Plan](#). It aligns with the [2014 Multi-Modal Active Transportation Master Plan \(MMATMP\)](#) and [2014 Official Plan](#), and it further develops the life cycle analysis and asset management principles outlined in the [2015 Corporate Asset Management Plan \(AMP\)](#). These principles assist the City to achieve expected level of service and life cycle sustainability for transportation assets.

The manual is also developed in alignment with the City of Barrie [2014 Urban Design Manual \(UDM\)](#) and [2009 Storm Drainage and Stormwater Management Policies and Design Guidelines](#). Relevant sections from these documents are referenced within this manual where applicable.

The information found in this manual shall be used in conjunction with the terms pertinent in the Subdividers Agreements and/or site plan agreements issued by the City of Barrie. The information in this manual will be a supplement to any additional or updated specification, approved by the City of Barrie. In addition to this manual, refer to the City of Barrie Standard Drawings (BSDs) provided in *Appendix A*.

### 1.1 Definitions

In this manual, the following definitions shall apply:

**“Boulevard Pathway”** shall mean an active transportation asset within a municipal ROW, usually asphalt surfaced, parallel to the roadway and typical width is 3.0m. The defining characteristic of a “Boulevard Pathway” is that the use is for all active transportation modes, often utilitarian in nature. This does not include multi-use trails located within park lands.

**“City”** shall mean the Corporation of the City of Barrie and any person assigned to a project by the City to carry out work on their behalf. The name of the representative shall be specified prior to the start of any project.

**"Contractor"** shall mean the firm of contractors, the company or individual acting as the contractor and having entered into a contract with the developer/owner to construct the roadway, services and/or appurtenances.

**“Designer”** shall mean qualified professional authorized to practice in Ontario, who provides expertise in the required discipline. The designer shall also include the consulting engineering firm who acts on behalf of the developer/owner.

**“Developer/Owner”** the registered developer of the lands for which a subdivision agreement has been entered into.

**“Development”**, as defined within the [Conservation Authorities Act](#):

- The construction, reconstruction, erection or placing of a building or structure of any kind,
- Any change to a building or structure that would have the effect of altering the use or potential use of the building or structure, increasing the size of the building or structure or increasing the number of dwelling units in the building or structure,
- Site grading, or
- The temporary or permanent placing, dumping or removal of any material, originating on the site or elsewhere.

**"Highway"** means all common and public highways and shall include any bridge, viaduct or structure forming part of a highway, and any public square, road allowance or walkway and shall include not only the travelled portion of such highway, but also ditches, driveways, sidewalks, and sodded areas forming part of the road allowance now or at any time during the term hereof under the jurisdiction of the City.

**"Residential"** developments having to do with construction of homes ranging from single family homes to apartments and condominiums.

**"Sidewalk"** shall mean an active transportation asset within a municipal ROW, usually parallel to the roadway and includes perpendicular segments when connecting to the roadway (i.e. ramps, offsets, and waiting areas). This does not include concrete bus pads, trails, or walkways.

**"Subdividers Agreement"** defines the obligations and duties of the developer/owner with respect to the subdivision of lands.

**"Walkway"** shall mean an active transportation asset between two municipal ROW or from a municipal ROW to non-park lands. This does not include trails or sidewalks. A defining characteristic of a walkway is usually a well-defined parcel of land, perpendicular to the municipal ROW with fencing or other barrier.

## **1.2 Abbreviations**

IRI	International Roughness Index
LCCA	Life Cycle Cost Analysis
ME	Mechanistic-Empirical
MEPDG	Mechanistic-Empirical Pavement Design Guide
MMATMP	Multi-Modal Active Transportation Master Plan
OPSD	Ontario Provincial Standard Drawings
OPSS	Ontario Provincial Standard Specifications
OTM	Ontario Traffic Manual
TAC	Transportation Association of Canada

### **1.3 External Guidance**

All roadway system components shall meet the minimum requirements of all applicable current industry standards and specifications for quality management and quality control, such as the Transportation Association of Canada (TAC), [Ontario Provincial Standard \(OPS\)](#) and the [Ontario Traffic Manual \(OTM\)](#). Designers, developers, and contractors shall ensure that designs are in accordance with when carrying out the design and construction of roadway infrastructure projects within the City of Barrie.

This manual should be considered as minimum guidelines, and provides the City's design preferences under normal circumstances. The designer however, should use best judgment to find innovative solutions when abnormal design conditions are encountered. For pavement design, the methodology outlined is to be followed by designers, developers, and contractors.

### **1.4 Deviations from the Transportation Design Manual**

This manual and associated standards have been developed in consideration of public safety, industry best practice, the City's ability to operate and maintain infrastructure, lowest lifecycle costing, emergency access, accessibility, the City's MMATMP, and UDM. Deviations from the requirements of this manual may be permitted when site constraints (e.g. natural heritage or other considerable challenges) prohibit the application of the prescribed requirements. No deviations to standards shall be permitted without the approval of the Director of Engineering or designate.

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## 2 Transportation Design Standards and Guidelines

This section of the manual establishes the City's acceptable design guidelines for roads and right-of-way (ROW) elements to be followed by designers, developers, and contractors for the design and installation of road infrastructure in the City. These guidelines ensure that the direction of the Official Plan, the MMATMP, the AMP and other City Council approved policies are implemented by designers, developers, and contractors throughout all the elements of the ROW.

### 2.1 Roadway Classification and Geometric Design

Roadway classification defines the function of the road segment and assists in transportation planning and design. In this manual, roadway classification and design vehicle are used to establish road cross-section design, pavement structure design, sidewalk requirements, and other ROW details. Planned new and widened roadway classifications are specified in the [MMATMP](#) dated January 2014. A description of roadway classification and characteristics is provided in *Table 1*. The basis is the TAC Geometric Design Guide for Canadian Roads (2017) where applicable, but nomenclature is specific to the City.

**Table 1 – Characteristics of Typical Roadway Cross Sections**

Characteristic	Arterial	Collector	Local
General Function	Carries moderate to high traffic volumes, providing through routes across and within City.	Carries moderate traffic volumes between arterial and local roads. May be designated Major or Minor, Residential or Industrial	Carries low traffic volumes, providing access to abutting lands. May be designated Residential or Industrial
Volume of Traffic, typical both directions, in vehicles per day (vpd)	Usually over 10,000 vpd.	Industrial areas: less than 12,000 vpd. Residential areas: less than 8,000 vpd.	Industrial areas: less than 3,000 vpd. Residential areas: less than 1,000 vpd.
Intersection and Access	Intersection with arterial and collector roads. Access may be restricted to right-in/ right-out only.	Intersection with arterial, collector and local roads. Access may be restricted to right-in/ right-out only.	Intersection with collector and local roads (arterial roads discouraged). No access restrictions.
Parking	Prohibited or peak hour restrictions.	Peak hour restrictions.	Per Zoning By-Law
Heavy Trucks	Standard highway tractor semi-trailer or larger vehicles where required.	Standard tractor semi-trailers.	Industrial: standard tractor semi-trailers. Residential: typically service and emergency vehicles only.
Transit Service and High Occupancy Vehicle (HOV) Lanes	Local and express buses. HOV lanes possible.	Local buses.	Transit buses generally not permitted.
Pedestrians	In accordance with <a href="#">Official Plan Amendment No. 38</a> , and City of Barrie Infill Sidewalk Policy (see section 2.3.5 of this document)		
Cyclists and Other Non-Motorized Users	Bike lanes both sides, buffered on roads with 4 or more lanes.	Bike lanes (not buffered) one or both sides.	None.

**Note**

Lakeshore Drive is the only City roadway designated as a parkway. It primarily provides for thoroughfare traffic and carries significant volumes of traffic.

**2.1.1 ROW Cross-Sections**

ROW cross-sections have been developed based on the recommendations in [Appendix I – Cross Sections](#) of the MMATMP dated January 2014. A ROW cross-section summary is provided in *Table 2*. Refer to *Appendix A* for the applicable BSDs. All bikes lanes are 1.5m wide. Buffered bike lanes have an additional 0.5m wide buffer.

**Table 2 – Widths of Typical Roadway Cross Sections**

Road Type	ROW Width (m)	Pavement Width (m)	Sidewalk Width (m)	Number of Lanes	Standard Drawing
<b>Local Roads</b>					
18.0m Local Road Allowance Residential	18.0	8.0	1.5	2	<a href="#">BSD-301</a>
20.0m Local Road Allowance Industrial	20.0	9.4	1.5	2	<a href="#">BSD-302</a>
<b>Collector Roads</b>					
24.0m Minor Collector Road Allowance Residential	24.0	12.5	2.0	2	<a href="#">BSD-303</a>
25.0m Minor Collector Road Allowance Industrial	25.0	13.25	2.0	3	<a href="#">BSD-304</a>
27.0m Major Collector Road Allowance	27.0	16.75	2.0	3	<a href="#">BSD-305</a>
<b>Arterial Roads</b>					
26.0m Arterial Road Allowance	26.0	14.2	2.0	2	<a href="#">BSD-306</a>
27.0m Arterial Road Allowance	27.0	15.2	2.0	3	<a href="#">BSD-307</a>
29.0m Arterial Road Allowance	29.0	18.0	2.0	4	<a href="#">BSD-308</a>
34.0m Arterial Road Allowance	34.0	22.2	2.0	4	<a href="#">BSD-309</a>
41.0m Arterial Road Allowance	41.0	29.2	2.0	6	<a href="#">BSD-310</a>
<b>Rural Roads</b>					
27.0m Rural Road Allowance	27.0	8.0	n/a	2	<a href="#">BSD-311</a>
36.0m Rural Road Allowance	36.0	8.0	n/a	2	<a href="#">BSD-312</a>
<b>Laneways</b>					
8.0m Laneway Road Allowance	8.0	6.0	n/a	2	<a href="#">BSD-313</a>
12.0m Laneway Road Allowance	12.0	7.0	1.5	2	<a href="#">BSD-314</a>

### 2.1.2 Laneways

Laneways are public roadways intended to convey motorists from a local roadway to a private access point (driveway, garage, etc.), and are not to be designed as a means to move traffic through a neighbourhood. As supported by the City of Barrie Official Plan, laneways may be accepted for use within the City of Barrie.

Laneways will be considered where direct driveway access from a street is not appropriate, or in response to special design features such as development fronting directly onto open spaced. Laneways shall be designed to provide access for public maintenance and emergency vehicles; and to maximize safety and security.

Laneways shall be designed in accordance with [BSD-313](#) and [BSD-314](#). Laneway widths are determined based on the servicing requirements for the development, though it is preferred that lots be serviced from adjacent local streets where feasible.

### **2.1.3 Geometric Design**

The geometric design of City roadways shall follow the latest edition of the TAC Geometric Design Guide for Canadian Roads (2017). Geometric design parameters specific to urban and rural design situations in the City are provided in *Table 3*.

**Table 3 – Geometric Design Details for Urban and Rural Cross Sections**

Geometric Parameter	Arterial	Collector	Local
Design Speed	70-90 km/h	70 km/h	60 km/h
Design Vehicle	WB-20 tractor semi-trailer or larger vehicles where required	Industrial: WB-20 tractor semi-trailer at moderate speeds Residential: WB-20 tractor semi-trailer at low speeds	Industrial: WB-20 tractor semi-trailer at low speeds Residential: WB-19 tractor semi-trailer at low speeds where possible
Width of Traffic Lane	3.5 m	3.5 m	3.0 to 3.7 m
Width of Turning or Two-Way Left-Turn Lane	3.25 to 4.2 m	3.25 m	-
Width of Parking Lane	-	2.5 m	2.0 m
Minimum Intersection Angle	Per TAC Section 9.7.2		
Minimum Intersection Spacing (measured from centerline to centerline)	Per TAC Section 9.4.2 See TAC Table 9.4.1 for signalized intersections		
Minimum Access Driveway Spacing (measured from edge of driveway to edge of pavement at adjacent intersection; distance refers to the length along the noted road classification)	Per TAC Section 8.9		
Minimum Access Driveway Control Distance to Intersection (as measured to nearest curb of intersection) <sup>1</sup>	Per TAC Section 8.9 70 m for commercial entrances		
Minimum Centreline Curve Radius	Per TAC Section 3.2		
Minimum Sightline Requirements	Per TAC Section 2.5		
Minimum Tangent Length Through Intersection	Per TAC Section 9.7.2		
Allowable Centreline Grades	0.5 to 5%	0.5 to 6%	Industrial 0.5 to 6% Residential: 0.5 to 8%
Allowable Centreline Grades at Controlled Intersections	0.5 to 2%	0.5 to 2.5%	Industrial: 0.5 to 3% Residential: 0.5 to 4%
Minimum Crest Vertical and Sag Vertical Curve K Factor (Urban, Illuminated)	Per TAC Section 3.3.3		

Note: Minimum horizontal curvature and minimum vertical curvature shall not be used at the same location. Vertical K factors shall be applied with all profile grade changes greater than 1%.

## **2.2 Intersection Design**

### ***2.2.1 Traffic Signal or Stop Control***

Curb radii or curb return radii for urban intersections under traffic signal or stop control shall be designed in accordance with [BSD-323](#). Refer to [BSD-324](#) and [BSD-325](#) for curb radii and intersection design for semi-urban roads. Curb radii are determined based on the classification of each intersecting road at a given intersection. Radii are measured from edge of pavement.

Transition treatments (i.e. lane widening or narrowing to introduce turning lanes) shall be as specified in the TAC Geometric Design Guide for Canadian Roads, Sections 9.13, 9.14 and 9.17.

All City roads shall be designed to accommodate routine plowing and winter maintenance. However intersection curb radii may need to be increased on truck routes where higher volumes of large trucks (tractor semi-trailers) are expected, as identified in [City of Barrie Traffic By-Law 80-138, Schedule N](#). The City shall be consulted to determine if an intersection is deemed part of a truck route and approval from the City is required if curb radii are to be increased from BSD requirements. In determining curb radii for truck routes in areas with heavily pedestrian movement consideration should be given to maintaining minimum curb radii to reduce pedestrian crossing distances.

### ***2.2.2 Roundabout Control***

Roundabouts shall be designed in accordance with good geometric design principles, including development of appropriate speed control and accommodation of a design vehicle. Design guidance shall be in accordance with the [National Cooperative Highway Research Program \(NCHRP\) Report 672, Roundabouts: An Informational Guide, Second Edition](#). Design vehicles shall be as noted in *Table 3*. Buses and emergency vehicles shall be accommodated without use of the central island truck apron on collector and arterial road roundabouts. Refer to [BSD-326](#), [327](#) and [328](#) for schematic details for pedestrian and cycling movements through roundabouts.

Centre features shall be installed in accordance with *section 2.4.9*.

## **2.3 ROW Considerations**

### ***2.3.1 Active Transportation***

Through the framework of the Official Plan and the Multi-Modal Active Transportation Plan, the City is looking to develop city streets as urban, multi-modal transportation corridors that safely accommodate pedestrians, cyclists, transit and vehicular movement for people of all ages and abilities. Traffic calming strategies are employed to improve the safety characteristics for pedestrians and cyclist. Boulevard spaces with enhanced streetscapes and amenities foster an urban character, supporting local business activity and accommodating the safe movement of people. In residential areas, sidewalks are integrated linkages placed to maximize connections for residents, creating safe and natural passages through neighbourhoods to local amenities including parks, commercial areas, recreation centres and schools.

Active transportation planning and design should be undertaken in close collaboration with land-use, transit and road planning. In existing developments, active transportation projects should be tied in with road and urbanization projects in order to accelerate the implementation of these measures and reduce capital costs. Transportation infrastructure can also apply Active and Safe Routes to School programs to enhance personal safety and encourage the use of active modes for the youngest users. Smaller local services, meeting places and civic areas within neighbourhoods should be located near schools and be accessible without requiring the use of an automobile.

### **2.3.2 Traffic Calming**

Traffic calming is the implementation of physical measures to alter motorist behaviour on a street or street network. Traffic calming also includes traffic management, which involves changing traffic routes or flows within a neighbourhood. Traffic calming is intended to improve the quality of life for residents on traffic calmed streets, achieve slower speeds for motor vehicles, and increase the safety and the perception of safety for non-motorized users of the street. Traffic calming is also intended to promote increased pedestrian, cycle and transit usage in an effort to help reduce the negative effects of motor vehicles on the environment.

The objective of traffic calming is to achieve uniform driving patterns at reduced travel speeds. That objective is consistent with resident expectations on roads where lower speeds are desired to enhance safety and livability in communities and neighbourhoods. That objective is not tenable on roads where higher speeds are desired. Consequently, physical traffic calming should not be used on roads intended for higher speeds or to move large volumes of traffic such as arterial roads

Permanent traffic calming measures are to be implemented in accordance with the City of Barrie [Traffic Calming Policy](#). For warranting criteria, refer to Traffic Calming Policy Appendix A for retrofit applications, and Traffic Calming Policy Appendix D for greenfield applications. The TAC Canadian Guide to Neighbourhood Traffic Calming would be utilized to provide design guidelines in selecting the appropriate traffic calming measures. Designers should consider various constraints including local climate conditions, environmental impacts, emergency response times and design vehicles that operate in subdivisions.

### **2.3.3 Daylighting Requirements**

A daylighting triangle is the area of a corner lot formed by measuring from the projected point of intersection between the two ROW from a specific distance back along each ROW line. Daylighting triangles are required where collector and arterial roads intersect to ensure adequate sight distances can be maintained between approaching drivers. Daylighting triangles are not typically required where local roads intersect, unless geometrically constrained (i.e. intersection angle below 70°). In such cases, minimum sightlines are to be provided for pedestrian and vehicular traffic.

Daylighting triangles for traffic signal or stop control intersections shall be in accordance with [BSD-323](#).

Daylighting triangles shall be determined independently for roundabouts through the design process. Refer to [BSD-325](#) and [BSD-326](#).

Where no sidewalk exists on the cross street the default location of the stop bar shall be 3.0 m from the road edge. Where sidewalk does exist on the cross street the default location shall be 2.0 m behind back of sidewalk. In constrained urban locations design vehicle movements shall be checked to determine if the stop bar needs to be staggered or set farther back to avoid the swept paths of large trucks or buses.

### **2.3.4 Driveway Access Management**

Driveway access shall be designed in conformance with the UDM. Refer to design criteria in *Table 3*.

Driveway access shall be designed with consideration to land use, driver expectation and pedestrian usage. Where large numbers of turning volumes are expected an auxiliary lane shall be considered. On arterial roads with six lanes or greater, a right-in/right-out access is required.

### **2.3.5 Clear Zone Requirements**

A clear zone is the area along the edge of a roadway available for safe use by errant drivers. It may consist of auxiliary lanes, curbs, shoulders, recoverable and non-recoverable slopes. Where fixed objects are to be placed in the boulevard along roads with a curb, locations shall be selected such that operational equipment has sufficient space and the likelihood of an impact by an errant vehicle is minimal. Fixed objects shall be placed such that sightlines for drivers and pedestrians are not blocked or obscured.

Where a curb is present, fixed objects including utilities and street furniture shall be a minimum of 1.0 m behind the back of curb to the nearest part of the object. Street lights and signal equipment shall be no less than 1.0 m behind the back of curb.

Where a curb is not present, fixed objects shall be placed in accordance with the TAC Geometric Design Guide for Canadian Roads, Sections 7.3 and 7.4.

### **2.3.6 Sidewalk Requirements**

Sidewalks shall be provided on both sides of all streets with the exception of the following locations where sidewalks shall only be required on one side of the street:

- Local streets in industrial areas;
- Residential streets with less than ten dwelling units or cul-de-sacs;
- Window streets; and,
- A street flanking the Natural Heritage System or a public park.

The City may also give consideration to permitting one sidewalk on local streets, once the City is satisfied through the submission of a Pedestrian Circulation Plan, that only one sidewalk is acceptable and provided that the street is not a transit route, does not provide direct access to a school, shopping area, park or village square, and the street has a maximum ROW width of 18 m. The geographic extent of the Pedestrian Circulation Plan shall be sufficient to demonstrate

how the above conditions are met, as well as the relationship of the area to the transit system, community facilities and shopping areas.

Within the Pre-2010 City Boundary identified within the MMATMP, arterial and collector roads shall be constructed to have sidewalks on both sides. Local roads (except for short cul-de-sacs of less than approximately 10 homes) to have at least one sidewalk

Roads fronting schools to have sidewalks on both sides from the school property to a logical termination point to maintain network connectivity and maintainability (approximately 250 m).

Sidewalks shall terminate at logical locations to ensure network connectivity and maintainability. Receiving sidewalks/ramps are required at all locations where pedestrians are directed to cross the roadway.

### **2.3.7 Snow Storage Requirements**

Roadway cross sections are such that the width of the boulevard allows snow banks to accumulate. Utilities and street furniture shall be located such that space for snow storage from roadway and sidewalk winter maintenance is sufficient.

## **2.4 Standards for ROW Elements**

### **2.4.1 Concrete Curb and Gutter**

Concrete barrier curbs and gutters shall be constructed in accordance with [OPSD 600.040](#) drawings and conform to [OPSS 353](#) in terms of minimum compressive strength.

Curb depressions are required at roadway intersections as specified in [BSD-316](#), [BSD-317](#) and [BSD-318](#).

### **2.4.2 Concrete Sidewalk**

**(REVISED)**

Sidewalks shall meet the minimum requirements of [Ontario Regulation 413/12, Accessibility for Ontarians with Disabilities Act, 2005](#), and conform to the minimum widths outlined in *Table 2*. Concrete sidewalk ramps shall be designed in accordance with [BSD-316](#), [BSD-317](#) and [BSD-318](#).

All new sidewalk ramps at intersections shall include cast iron tactile warning surface indicators (TWSI's). Sidewalk ramps that are reconstructed for any reason should be retrofitted with cast iron TWSI's. TWSI's shall be in conformance with [OPSD 310.039](#).

Concrete sidewalks shall have a minimum thickness of 125 mm except where adjacent to curb or through residential driveways in which they shall be a minimum thickness of 150 mm. Ramps shall have a minimum thickness of 200 mm with flared sides adjacent to ramps having a minimum thickness of 150 mm. Sidewalks through industrial or commercial driveways shall have a minimum thickness of 200 mm. Concrete shall conform to [OPSS 351](#) in terms of minimum compressive strength.

Bedding under concrete sidewalks shall be granular 'A' and shall have a minimum thickness of 150mm.

Concrete sidewalks through driveways shall conform to [OPSD 310.050](#).

Concrete sidewalk ramp locations take precedence over proposed driveway locations.

### **2.4.3 Boulevard Pathway**

The width for asphalt boulevard pathways shall be designed and constructed per [BSD-320](#), and be wider (i.e. 3.0 m) in areas of moderate to high activity. Pathways shall have a minimum lateral clearance table of 0.5m each side.

For boulevard pathway design at intersections, refer to [OTM Book 18](#).

Side slopes or tapers from boulevard pathways shall be no steeper than 3:1. Pathways, unlike walkways, shall not be raised.

Base material shall conform to OPSS criteria.

### **2.4.4 Walkways**

Walkways shall be designed in accordance with Ontario Regulation 413/12, Accessibility for Ontarians with Disabilities Act, 2005. Walkways shall be a minimum of 1.5 m wide. They shall be raised 0.15 m and hard surfaced with material other than asphalt to ensure that pedestrians are able to distinguish from parking areas.

Concrete walkways shall conform to the same minimum thickness, bedding and compressive strength requirements as concrete sidewalks.

### **2.4.5 Driveways and Entrances**

Driveways and entrances shall be designed in accordance with [BSD-319](#).

Driveway typical widths shall be in accordance with the City's [Zoning By-Law 2009-141](#) and UDM, unless otherwise approved by the City.

As specified in the [Lot Grading and Drainage Standards and Design Manual](#), driveways shall not have reverse slopes unless otherwise approved by the City.

Minimum control distances on intersection approaches, minimum spacing between driveways, minimum spacing between driveways and sidewalk ramps, entrance aprons and other aspects of driveway design are detailed in Section 3.4 of the City's UDM. Minimum clear distance requirements between driveways and utility structures, hydrants or trees shall be determined using clear zone methods. See *Section 2.3.4* of this manual.

Materials shall conform to OPSS criteria and surface material other than asphalt shall be approved by the City.

### **2.4.6 Boulevards**

Boulevards are defined as the area between the property line and the back of curb. They shall be sodded unless otherwise approved by the City. Topsoil and sod shall conform to the City of Barrie Lot Grading and Drainage Standards and Design Manual.

Boulevards shall be constructed with positive drainage at the same slope as the driveway per *Section 2.4.5* in this manual.

Ditches shall be constructed in rural ROWs as indicated in [BSD-311](#) and [BSD-312](#).

#### **2.4.7 Road Subdrains**

Road subdrains shall be constructed along both sides of all roads with curb and gutter. Subdrains shall conform to [BSD-315](#). Type A subdrain shall be used in most instances. Type B, with clear stone, shall be used for high groundwater environments.

Subdrains shall drain into catchbasin locations where available or other stormwater outfalls such as roadside ditches or storm sewers.

#### **2.4.8 Utilities**

All proposed new utility installations within municipal ROW require Municipal Consent from the City's Corporate Asset Management Branch and a Right of Way Activity Permit.

Refer to BSD-301 to BSD-314 for typical location of utilities within the boulevard.

Any utility ducts required to cross roads shall be confirmed with the utility company during the design process. All ducts must be placed in conjunction with road base construction and prior to installation of subdrains. Any duct crossings required after base asphalt is placed shall be directional bored.

#### **2.4.9 Medians and Traffic Islands**

Median islands are required on arterial roads having six or more through lanes to separate opposing flows of traffic. Medians shall be designed to provide space for left-turn lanes, snow storage and pedestrian refuge. Median island width is measured from the left edge of the travel lane and appropriate width shall be determined through the design process.

Medians shall be designed for visibility during day and night and contrast with the roadway, with proposed treatments to be approved by the City. The use of concrete is preferred. Interlocking bricks and river stone shall not be used.

Medians shall be raised throughout their length unless depressed sections are needed for emergency or residential driveway access. Barrier curbs shall be used for the raised sections. If medians are used for extended distances then the City shall be consulted to determine the best means of access for emergency vehicles.

Medians shall be graded with a crown and minimum slope of 2% to allow positive drainage.

Note that the foregoing is also applicable to splitter islands at roundabouts.

For the design of medians and traffic islands, such as those found at channelized right-turn lanes, refer to the TAC Geometric Design Guide for Canadian Roads, Section 9.15.

#### **2.4.10 Bus Stops and Peripheral Furniture**

Bus stop location, placement and concrete furniture shall be provided at the direction of the City, and shall be designed and constructed in accordance with [BSD-321](#). An expansion joint is required between the curb and concrete pad. Steel mesh for the concrete pad shall be in accordance with [BSD-322](#).

Other peripheral or street furniture, such as bollards, mailboxes, benches, and trash cans, are only to be placed within the boulevard subject to approval from the City. Furniture shall not be placed on sidewalks, boulevard pathways, driveways or other accesses and shall be limited in size such that driver and pedestrian sightlines are not obstructed in accordance with *Section 2.3.1* of this manual.

#### **2.4.11 Road Safety Elements**

Road safety barriers are protective devices installed between motor vehicle traffic and a potential hazard off the roadway. Examples include cable guide rail, box beam guide rail and concrete Jersey barrier. Where clear zone requirements as set out in *Section 2.3.3* of this manual cannot be achieved, safety barriers shall be constructed where they will cause less damage when struck compared to a fixed object hazard such as a utility pole.

For safety barrier requirements, refer to the TAC Geometric Design Guide for Canadian Roads, Section 7.6. To calculate approach length of the safety barrier system refer to Figure 7.6.6, and for departure length refer to Figure 7.6.7.

Type of safety barrier shall be recommended by the designer for approval by the City. For guide rail system standard details, refer to the OPSD 900-series drawings.

#### **2.4.12 Roadside Drainage**

Road grading shall direct flows from the ROW to a safe outlet at specified low points.

In urban cross-sections, catchbasins or LID facilities shall be constructed to manage flows in accordance with the Storm Drainage and Stormwater Management Policies and Design Guidelines. Roads may be used for major system overland flow conveyance for a Regulatory storm, subject to ponding depth constraints. LID facilities shall be incorporated into the ROW as applicable.

For semi-urban and rural cross-sections, ditches shall be constructed according to the Storm Drainage and Stormwater Management Policies and Design Guidelines Section 3.4.2.

### **2.5 Cul-de-Sac**

Temporary residential cul-de-sacs shall conform to [BSD-329](#) and are only permitted in order to accommodate short term development phasing and are subject to approval by the City. Permanent cul-de-sacs are not endorsed by the City.

### **2.6 Trench Reinstatement**

All areas disturbed shall be reinstated to a condition equal or better than existing conditions. Final restoration shall be in accordance with [BSD-330](#).

#### **2.6.1 Driveway Restoration**

Open cutting of driveways is not permitted.

### **2.6.2 Backfilling**

Following installation of the pipe(s), pipe bedding and surround, the trench shall be backfilled with native soil placed in compacted layers at a maximum pre-compaction thickness of 300 mm. The trench backfill shall extend from the pipe cover to the bottom of the granular base layer. The top lift of backfill material shall be shaped to slope from the centreline down at 3% towards the edge of shoulder.

In the event that the existing soil is not suitable for use as backfill, granular B must be used. Backfill shall be compacted to a minimum 95% Standard Proctor Density (SPD).

Should the layer to be backfilled with native soil be less than 1200mm, the entire depth of the cut shall be re-instated using a frost taper with a slope of 15:1 as per [OPSD 803.030](#). The frost taper shall be backfilled with granular "B" in lifts not exceeding 200mm thick. Granular "B" in the frost taper shall be compacted to 100% SPD.

During winter months, the contractor is permitted to backfill with unshrinkable fill. Fill area is to be protected with a steel plate until material has set. Unshrinkable fill specifications shall be 25 kg/m; cement, concrete aggregates, 0.07 MPa (10 PSI) within 24 hours and not to exceed 0.4 MPa (60PSI) at 28 days, with air-entraining admixture to reduce segregation slump of 160 mm to 200 mm.

Upon prior approval from the City, unshrinkable fill may be used in intersections and on arterial/collector roads where there is high traffic volumes to reduce downtime and the chances of settlements.

### **2.6.3 Granular Base/Subbase**

The existing granular base shall be cut back at a 1:1 slope from the top of the sub-grade elevation. If re-instating with a frost taper the existing granular base shall be cut back at a 15:1 slope. Re-instatement of granular material shall match existing. The minimum accepted compaction for the granulars shall be 100% SPD in lifts not exceeding 200mm thick.

The top of the granular "A" base material shall be shaped to slope from the centreline down at 2% towards the edge of shoulder and level with the bottom of the existing asphalt.

Just prior to placing the asphalt the granular surface shall be re-graded and re-compacted.

### **2.6.4 Joints**

The existing asphalt shall be saw cut a minimum of 300 mm back from the top of the edge of the new granular. Cutting must be done by means of saw cutting to leave a clean, straight edge with vertical sides.

All joints are to be stepped by grinding and all faces against which joints are to be made shall be painted with a thin, continuous and uniform coating of asphalt emulsion complying with [OPSS form 1103](#).

### **2.6.5 Asphalt Restoration**

Road cuts are to be immediately replaced with hot mix asphalt. Road cuts may be restored with cold mix asphalt during the winter months as a temporary patch only. As soon as hot mix asphalt becomes available in the spring the temporary cold mix patch must be replaced with asphalt thicknesses matching existing.

Pavement structure shall follow the City's minimum standards or match the existing pavement structure, whichever is greater.

### **2.6.6 Pavement Markings**

The contractor shall be responsible for restoring pavement markings in accordance with OTM.

### **2.6.7 Concrete curb and Gutter**

Damaged sections of concrete curb and gutter shall be removed and replaced per *section 2.4.1*

### **2.6.8 Sidewalks**

All damaged sections of sidewalk will be removed and replaced per *section 2.4.2*.

### **2.6.9 Boulevards**

Trenches shall be backfilled with native material to the original grade to a minimum of 95% of the maximum SPD. Topsoil and sod shall be placed in accordance with the City of Barrie's Lot Grading Design Guidelines.

All sodded boulevard damaged or excavated during the winter months shall be back filled immediately with granular "A" gravel up to existing grade until permanent repairs are completed in the spring. All excavations completed during the winter months must be fully restored with topsoil and sod by May 31st of each year.

Disturbed areas must be sodded within 1 week of backfilling.

#### **2.6.9.1 Restoration of Trees, Shrubs and Bushes**

All trees, removed shall be replaced with equal quality nursery stock of a minimum caliper of 50mm. Shrubs and bushes removed shall be replaced with equal quality of the same age and size

#### **2.6.9.2 Peripheral Furniture**

All signs and peripheral furniture along the line of excavation shall be removed, and reinstated by the contractor.

#### **2.6.9.3 Fences and Guide Rails**

Fences and guide rails shall be dismantled at the location shown on the approved drawings.

Fences and guide rails shall be restored with the same type of fence or guide rail that existed prior to construction, or as specified by the City. All broken, bent and damaged components shall be removed from the site and replaced with new components. All reusable components shall be stored and protected.

### **3 Pavement Design Methodology**

#### **3.1 Pavement Management and Pavement Design Objectives**

“Pavement management” encompasses a wide spectrum of activities including the planning and programming of investments, design, construction, maintenance and the periodic evaluation of performance. The function of pavement management at all levels involves comparing alternatives, coordinating activities, making decisions and seeing that they are implemented in an efficient and economical manner. The objective of pavement design is to develop a cost-effective pavement structure that addresses site specific performance, serviceability and safety requirements over the life of the pavement. It requires an understanding of soils and paving materials and their behaviour over time under different traffic loading and climatic conditions. This section of the manual will focus primarily on pavement design for new construction and rehabilitation, including widenings.

The pavement design engineer shall recommend the pavement type and thickness of the pavement layers of the pavement structure based on inputs such as subgrade conditions, materials, traffic, climatic, economic, and other considerations. Throughout *Section 3* of the manual, the pavement design engineer will be referred to as the designer.

#### **3.2 Pavement Design Process**

The City has adopted a three step pavement design methodology to be followed in all pavement designs: (1) structural design, (2) economic analysis, and (3) other considerations, as depicted in Figure 1 and further explained in the remainder of *Section 3*.

#### **3.3 Pavement Design Deliverables**

The pavement design process is an iterative process as data is collected and alternatives are considered. The following delivery milestones shall be submitted by the designer to the City:

- Preliminary Pavement Proposal (by 30% of overall project schedule)
- Final Pavement Design (by 60% of overall project schedule)
- Pavement Design Final Submission (by 100% of overall project schedule).

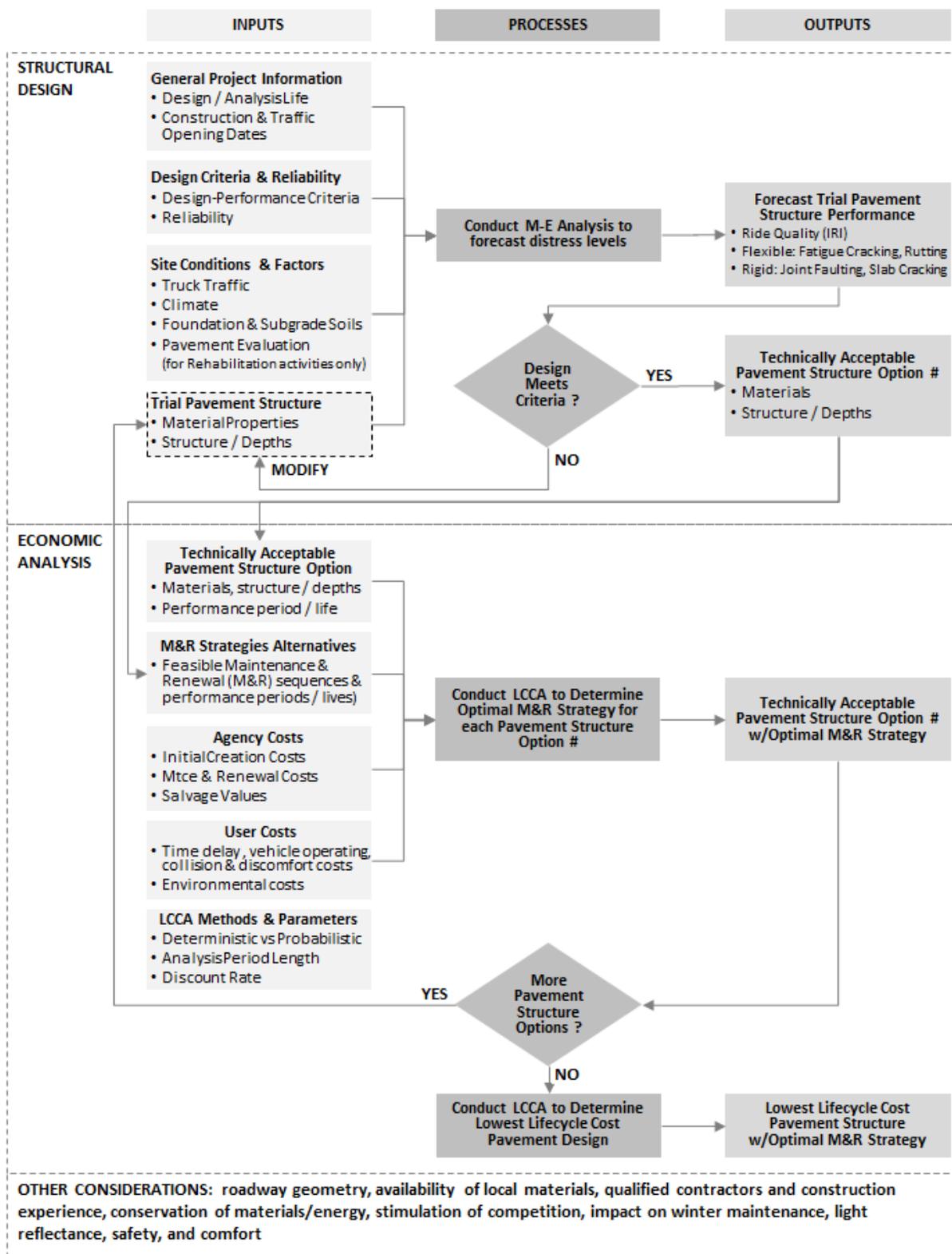
*Table 4* provides an overview of the pavement design deliverables.

#### **3.4 Structural Design**

Pavement structural design shall be undertaken in accordance with the Mechanistic-Empirical (ME) pavement design methodology as outlined in the [Mechanistic-Empirical Pavement Design Guide \(MEPDG\) Manual of Practice](#) issued by American Association of State Highway and Transportation Officials (AASHTO) in 2008. Inputs include design life, performance criteria and site factors such as truck traffic, climate and foundation and subgrade soils, and, in addition for rehabilitation and widening works, existing pavement history and condition. The Ministry of Transportation Ontario (MTO) has been working towards adoption and validation of the ME Pavement Design procedure for Ontario conditions, and has published an interim report, dated November 2012, and titled “[Ontario’s Default Parameters for AASHTOWare Pavement ME](#)”

Design” (“Ontario’s Default MEPDG Parameters”). The designer shall use this interim document as a guide to input parameters for Ontario conditions, as detailed in Sections 3.4.1 to 3.4.8.

**Figure 1 - Pavement Design Flow Chart**



MEPDG uses a hierarchy-based approach to design inputs, allowing the designer flexibility in obtaining the design inputs for a project. Level 1 inputs are project or site-specific. Level 2 inputs are estimated from correlations, derived from a limited testing program, or from the owner database. Level 3 inputs are typical values for the local region. The designer shall select a predominant level of inputs, and provide inputs at this selected input level as much as possible. For local roads, Level 3 is adequate. For minor arterials and collectors, Level 2 or 3 is appropriate. For higher traffic arterials, Level 1 or Level 2 is to be used if possible. In addition to criticality of the road, final selection of the input hierarchy level will depend on availability of information and sensitivity of the pavement performance to a given input. Ontario's Default MEPDG Parameters guide provides guidance for input parameters mainly at Level 3.

**Table 4 Pavement Design Deliverables Summary**

Sub-Section	Description	Preliminary Pavement Proposal (30%)	Final Pavement Design (60%)
<b>Executive Summary</b>			
Project Scope	Describe the project scope, including roadway names and stations, as applicable.	Yes	Yes
Design Procedure and Life	Identify design procedure used and design service life for all new work and rehabilitation sections included in the report.	Yes	Yes
Recommended Pavement Design	Identify recommended pavement design(s) for all existing and new pavement features.	Yes	Yes
Recommended Materials and Specifications	Recommend materials to be used (reference applicable specification and bid item nomenclature).	Yes	Yes
Any Required Modifications To Specifications	Identify any required modifications to special provisions or specifications.	NA	Yes
<b>Structural Design Inputs</b>			
General Project Information	Provide the design life and construction and traffic opening dates.	Yes	Yes
Design Criteria & Reliability Levels	Identify performance criteria and level of reliability for smoothness and each distress type, by roadway classification, against which the trial pavement structures will be compared.	Yes	Yes
<b>Site Conditions &amp; Factors</b>			
Truck Traffic	Outline the truck traffic inputs used for evaluating the adequacy of each pavement design, including the growth of truck traffic during the pavement life.	Yes	Yes
Climate	Identify the input climate data used to predict the temperature and moisture content in each of the pavement layers.	Yes	Yes

Sub-Section	Description	Preliminary Pavement Proposal (30%)	Final Pavement Design (60%)
Foundation & Subgrade Soils	Summarize the field investigation activities and results, with photographs and vicinity map.	Propose Investigation (2)	Yes
Pavement History, as required (1)	Summarize historical "as-built" construction information, including previous and last treatments and age of pavement (if available).	NA	Yes
Pavement Condition, as required (1)	Document existing pavement condition including severity and extent of distresses, causes of distresses, whether distresses are functional versus structural, with photographs.	Propose Investigation (2)	Yes
<b>Structural Design</b>			
Mechanistic-Empirical Analysis	Evaluate structural capacity of the alternatives based on the AASHTO Mechanistic-Empirical Pavement Design Guide (MEPDG) Manual of Practice.	Yes	Yes
Structural Design Results	Document the technically acceptable pavement structures (material types and layer depths) that will be considered in the economic analysis with the predicted pavement performance, compared to the preset performance requirement, and document at least one failed iteration for each technically acceptable pavement structure to demonstrate that an iterative analysis was undertaken.	Yes	Yes
<b>Economic Analysis Inputs</b>			
LCCA Methods & Parameters	Document economic analysis options including analysis period, discount rate, beginning of analysis period, etc.	NA	Yes
Maintenance & Renewal Strategies Alternatives	Document alternative pavement lifecycle activities, timing and estimated service lives.	Yes	Yes
Agency Costs	Document, as applicable, initial and rehabilitation costs, maintenance costs, salvage value.	NA	Yes
User Costs (future consideration)	Document, as applicable, time delay costs, discomfort costs, vehicle operating costs, collision costs, environmental costs	NA	Not at this time
<b>Economic Analysis</b>			
Life Cycle Cost Analysis (LCCA)	Undertake a LCCA of the technically acceptable pavement structure options or rehabilitation treatments in accordance with Ministry of Transportation, Materials Engineering and Research Report MERO-018, dated March 2005, titled "Guidelines for the Use of Life Cycle Cost Analysis on MTO Freeway Projects". A deterministic LCCA approach may be used but	NA	Yes

Sub-Section	Description	Preliminary Pavement Proposal (30%)	Final Pavement Design (60%)
	shall include a sensitivity analysis to evaluate best case and worst-case scenarios to understand the impact of variability of the individual inputs on the overall LCCA results, including discount rates, unit costs, and activity timing.		
Economic Analysis Results	Document the LCCA analysis results, including the sensitivity analysis in summary tables or plots of present value versus individual input variables.	NA	Yes
<b>Other Considerations</b>			
	Outline considerations other than structural and economic impacts such as constructability issues or opportunities to evaluate new materials or technologies.	Yes	Yes
<b>Digital Deliverables</b>			
Digital Data	Submit data collected as part of the project	NA	Yes
Digital Reports	Submit reports in pdf format.	Yes	Yes

Notes:

- (1) Required for pavement designs which involve pavement rehabilitation, or reconstructions of new pavement on existing roadway (i.e. reconstruction).
- (2) The Preliminary Pavement Proposal will propose the requirement for further input data such as a geotechnical investigation, FWD data, cores, pavement condition, projected construction year traffic data.

As part of establishing the input parameters, the designer must select a trial pavement structure (combination of material types and layer depths) as provided in *Appendix C*. The designer shall predict pavement performance using the MEPDG, and compare the pavement performance prediction with the preset performance requirement, refer to *Section 3.4.2* below. Based on the ability of the trial pavement structure to meet the preset performance requirements of the trial pavement structure will be deemed technically acceptable or not. The designer shall continue to make iterative variances to the trial pavement structure, predict pavement performance, and compare the pavement performance prediction with a preset performance requirement until at least three (3) technically acceptable pavement structures are determined for a range of material types and layer depth.

The outputs of the structural design are technically acceptable pavement structures for flexible and rigid pavement types, including associated pavement layer thicknesses, which need to be economically analyzed and reviewed for other considerations.

For rehabilitation design, the designer shall model the condition of the existing pavement based on surface distress, pavement performance, and back calculated modulus values of the pavement layers from non-destructive testing using equipment such as the Falling Weight Deflectometer (FWD). The designer shall consider the current condition of the pavement as the

starting condition, and use the MEPDG to model the future distresses such as pavement cracking and roughness, for a range of trial rehabilitation designs. The designer shall then compare the trial rehabilitation pavement performance prediction to the design criteria. If the design criteria are met, the rehabilitation design (combination of material types and layer depths) is considered suitable for consideration in the economic analysis.

The following sections provide guidance on developing the inputs to the Structural Design in accordance with the ME Pavement Design methodology.

#### **3.4.1 Pavement Service Life**

The pavement service life or pavement performance period is the time period, in years, between new construction of a pavement and its first major rehabilitation, e.g. overlay or resurfacing, when performance has become inadequate. For rehabilitations, the service life is the time period between the rehabilitation and the next major rehabilitation. Typical Pavement Service Life within Barrie can be determined using the data on *Table 7*

For rehabilitation, widening and reconstruction works, the designer shall obtain historical records of the initial pavement structure and any subsequent pavement treatments from the City.

Based on the designer's experience, and guided by *Table 7* below and the City's assumed pavement service life for new construction (15 years for arterial roadway classifications, 15 years for collector roadway classifications, and 20 years for local roadway classifications), the designer shall estimate the performance life for the initial construction and any subsequent pavement treatments. The performance shown in *Table 7* are specific to Barrie, based on historical timing of the rehabilitation treatments, and do not take into account the current stage in a road segment's life cycle, or specific traffic and climate conditions.

The designer shall provide justification for the pavement service lives used in the analysis.

#### **3.4.2 Design Performance Criteria and Reliability Levels**

The performance criteria are important and sensitive to the analysis and the final design of the pavement. Initial IRI (mm/m) is the predictive International Roughness Index for newly-constructed pavement. The designer shall use the recommended Initial IRI (m/km) inputs provided in *Table 5* below.

The performance criteria of terminal serviceability represent the lowest acceptable condition that will be tolerated before rehabilitation is required. The terminal performance criteria to be used for various road classifications are provided in *Table 5* below. Design reliability is defined as the probability that the predicted distress will be less than the critical level over the design period. In *Table 5*, the level of reliability is set higher for higher traffic volume roadways in order to prevent premature failures.

**Table 5 - Design Performance Criteria, by Roadway Classification**

Pavement Type	Metric	Unit	Arterial	Major Collector	Minor Collector	Local
Reliability Level			90%	85%	80%	75%
All	Terminal IRI (smoothness)	m/km	5	6	7	9
Hot Mix Asphalt (HMA) pavement and overlays	Alligator cracking (HMA bottom up fatigue cracking)	%	10	20	25	35
	Rut depth (permanent deformation in wheel paths)	mm	9	10.5	12	15
JPCP new, CPR and overlays	Mean joint faulting	mm	6	-	-	-
	Percent transverse slab cracking	%	10	-	-	-

**3.4.3 Truck Traffic**

The MEPDG uses a rigorous process to estimate the traffic loads on a roadway. Light vehicles such as motorcycles and passenger vehicles are not considered in the analysis because the load applied is very low. The designer shall determine the Average Annual Daily Truck Traffic (AADTT) based on the average annual daily traffic (AADT), a percentage of the AADT in each of the 13 US Federal Highway Administration (FHWA) designated vehicle classes (classes 4 to 13), and an annual growth rate or expansion factor.

The commercial vehicle distribution (%) in each of the FHWA classes is dependent on the roadway classification, the location, and the proximity to industry and natural resources. The designer shall consider the typical distributions for the three roadway classifications shown in *Table 6* below, and modify inputs for local conditions as provided in “Ontario’s Default MEPDG Parameters”, Section 3.0 Traffic.

The Growth Rate value represents the growth of truck traffic during the pavement service life, and is typically linear, with the rate of increase remaining the same throughout the design period. The designer shall obtain the Traffic Growth Factor to be used in the ME pavement design from the City’s Traffic group.

**Table 6 - Expected Commercial Vehicle Distribution for Municipal Roadways**

TAC Classifications	Commercial Vehicle		Distribution of Commercial Vehicles		
			Major Arterial	Minor Arterial	Collector
B-12 A-BUS I-BUS		Two or Three Axle Buses	1.8%	3.3 %	2.9 %
LSU MSU		Two-Axle, Six-Tire, Single Unit Trucks	24.6 %	34.0 %	56.9 %

TAC Classifications	Commercial Vehicle		Distribution of Commercial Vehicles		
			Major Arterial	Minor Arterial	Collector
HSU		Three-Axle Single Unit Trucks	7.6 %	11.7 %	10.4 %
WB-19 WB-20		Five-Axle Single Trailer Trucks	31.3 %	36.2 %	15.3 %
ATD BTD		Seven or More Axle Multi-Trailer Trucks	15.3 %	0.3 %	0.3 %

### 3.4.4 Climate

As provided in “Ontario’s Default MEPDG Parameters”, Section 4.0 Climate, the climate inputs are based on project location. Currently, there are 34 weather stations in Ontario for which AASHTO periodically updates the climate inputs. The designer shall use the most relevant weather station for Barrie which is Oro-Medonte.

### 3.4.5 Structure Layer Information

The designer shall use the structure layer information as provided in MTO’s “Ontario’s Default MEPDG Parameters”, Section 5.0 Structure Layers Information.

### 3.4.6 Foundation & Subgrade Soils

Subgrade properties default values in the MEPDG Manual of Practice are based on the AASHTO soil classification system and are different than those typically used in pavement design in Ontario. The designer shall back calculate the subgrade and embankment moduli based on FWD testing using the factors provided in “Ontario’s Default MEPDG Parameters”, Table 30: Convert the Calculated Subgrade Embankment Layer Modulus Values to an Equivalent Resilient Modulus Measured in the Laboratory.

### 3.4.7 Pavement History (required for pavement rehabilitation & reconstruction designs)

The designer shall consider construction history in developing the field investigation strategy to determine the existing material types and depths, in evaluating the performance of existing materials, and in developing pavement rehabilitation and reconstruction designs. The City maintains a record of as-constructed drawings which can be used to obtain historical information. The designer shall obtain historical records of initial pavement structure and any subsequent pavement strategies from the City, but is cautioned that the information contained in the drawings is not always available or complete and does not necessarily include maintenance preservation work.

### 3.4.8 Pavement Condition (required for pavement rehabilitation & reconstruction designs)

The City conducts a network-wide pavement condition assessment on a four-year cycle, with the most recent assessment completed in 2014. The methodology for the pavement survey in 2014, which included the collection of roughness and surface distress data, followed the ASTM

D6433: Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys. The 2014 pavement condition survey was undertaken using laser road surface testing equipment.

The designer shall obtain historical pavement condition data from the City. Based on the review of the historical pavement condition data, observed current pavement condition, and proposed pavement works, the designer shall recommend whether further input data is required, including field investigations such as deflections measured with an FWD, exploration holes, pavement cores, rut depths, updated pavement distress survey and photographs, and laboratory testing to supplement the field investigation such as testing of materials. Guidance on the field investigation and laboratory testing is provided in *Appendix B*.

### **3.5 Economic Analysis**

The designer shall undertake a Life Cycle Cost Analysis (LCCA) of the technically acceptable initial pavement structure options or rehabilitation treatments and associated future maintenance and renewal activities in accordance with the MTO, Materials Engineering and Research Report MERO-018, dated March 2005, titled “Guidelines for the Use of Life Cycle Cost Analysis on MTO Freeway Projects”.

For each technically acceptable pavement structure option determined from the structural design process described in *Section 3.4*, the designer shall determine the lowest life cycle option by conduct a LCCA to determine the lowest life cycle cost pavement structure. Maintenance and Rehabilitation activities are outlined in *Table 7* below.

Inputs for the Economic Analysis include estimates of the initial construction costs and pavement service life, the maintenance, rehabilitation and reconstruction activities, timing, service lives and costs, and the salvage values. The following sections provide guidance on developing the inputs to the economic analysis.

#### **3.5.1 Deterministic LCCA**

A deterministic-based LCCA approach uses only the mean values to define all input parameters (i.e., discount rate, costs, service lives, timings) to develop a mean overall present value. A probabilistic-based LCCA uses mean and standard deviation values to define a probability distribution for a given input parameter. One input is allowed to vary according to a defined distribution (e.g., normal, uniform, exponential) while holding all other inputs at their mean value and computing the present value for each input.

The designer may use either a deterministic or probabilistic LCCA approach. If a deterministic approach is used, the designer shall conduct a sensitivity analysis to evaluate best case and worst-case scenarios to understand the impact of variability of the individual inputs on the overall LCCA results, including discount rates, unit costs, and activity timing. The sensitivity analysis shall be documented in summary tables or plots of present value versus individual input variables.

### **3.5.2 Analysis Period Length**

The analysis period is the number of years over which the pavement life cycle analysis is conducted. The analysis period shall include the initial pavement construction and at least one of the subsequent rehabilitation outlined in *Table 7*, and shall be the same for all alternatives. City life cycle cost analyses shall use a 50-year analysis period.

### **3.5.3 Discount Rate and Treatment of Inflation**

The discount rate is used to convert future expenditures into equivalent costs today. Real discount rates reflect the true value of money with no inflation premium and shall be used in conjunction with non-inflated cost estimates of future investments. The designer shall obtain the real discount rate from the City's Finance Department. Since discount rates can significantly influence the analysis results, the designer shall undertake a sensitivity analysis to determine if the alternate scenarios are discount-rate sensitive.

### **3.5.4 User Costs**

User costs are the delay, vehicle operating, and crash costs incurred by users of the facility over the life of the analysis period. Vehicle delay and crash costs are unlikely to vary among alternative pavement designs between periods of construction or maintenance. Although vehicle-operating costs may vary between pavement design strategies, there is little research on quantifying such cost differentials under the pavement condition levels at this time. The City does not require that user costs be included in the LCCA at this time.

### **3.5.5 Maintenance and Renewal Strategy Alternatives**

The designer shall establish feasible and cost effective initial construction pavement structure options and subsequent maintenance and renewal strategies. These strategies include establishing treatment type, time of application, and performance life.

Maintenance and rehabilitation activities for flexible and rigid pavement are outlined in *Table 7* below.

The designer shall ensure that the maintenance and renewal strategies, including treatment activities, times of application, and performance lives are technically acceptable by assessing them using the ME Pavement Design methodology.

**Table 7 - Pavement Maintenance and Rehabilitation Activities for Flexible and Rigid Pavement**

	MP L (yrs)	Flexible Pavements				Rigid Pavement		
		Rout & crack sealing	Micro-surfacing or Slurry Seal	Partial depth removal (milling) & resurfacing	Full depth removal &	Reseal Joints	Partial Depth PCC repair	Full Depth PCC repair
Arterial & Parkway	45	5/20	10/25	15	30	12/25/40	25/40	25/40
Major Collector	60	5/20	10/25	15	30	12/25/40	25/40	25/40
Minor Collector	60	7/22/37	-	15/30	45	12/25/40	25/40	
Local	70	10/30/55	-	20	40	-	-	-

**3.6 Other Considerations**

The output of the structural design (*Section 3.4*) and economic analysis (*Section 3.5*) is the pavement structure with the lowest lifecycle cost that meets the required performance criteria. However, the designer shall also consider factors other than structural performance and economics to base the selection of the most suitable pavement design as applicable, including the following:

- Geographic and topographic conditions
- Physiographic setting and subgrade soil characteristics
- Groundwater conditions
- Projected traffic loading
- Short term availability of funds
- Geometric design considerations
- Wearing surface factors – surface drainage, skid resistance, resistance to studded tires or chain wear, tire noise, etc.
- Availability of pavement materials
- Opportunity for recycling of pavement materials
- Availability of qualified contractors
- Mobility issues – Future grade limitations (vertical clearance), staging, etc.
- Number and complexity of future rehabilitation
- Safety of public, contractor, and maintenance during construction and maintenance activities
- Public perception
- Potential risks in availability of future overlay funds at planned times
- Opportunity for evaluation of new technologies.

The designer shall explain additional considerations evaluated in determining the final pavement design selection.

## APPENDIX A

# BARRIE STANDARD DRAWINGS (BSD)



## APPENDIX B

# FIELD INVESTIGATION AND LABORATORY TESTING GUIDELINES



## **1. Field Investigation**

### **Traffic Control and Utility Locates**

Traffic control and utility locates shall be conducted in accordance with the [City's Right Of Way Activity By-Law](#).

### **Deflections**

Deflections shall be measured with an FWD, in accordance with ASTM-D4694. Sensors must be located per the Strategic Highway Research Program (SHRP) Guidelines. The FWD's Distance Measurement Instrument must be calibrated to ensure proper distance measurement. Deflection testing is not required for the construction of roadways on new alignments. However, deflection testing of adjacent roadways may provide data for the backcalculation of subgrade resilient modulus that may be appropriate for new work design. The designer shall submit deflection data and analysis as well as FWD calibration information in accordance with **Table 4**.

- **Asphalt Concrete Pavement:** For widening of existing roadways consisting of asphalt concrete pavement (AC), deflections shall be measured on the shoulder at a maximum spacing of 75 m to help determine if the shoulders are structurally sufficient to carry travel lane traffic after widening. If the existing pavement is to be structurally overlaid in addition to widening, deflection testing is required. For pavement rehabilitation projects, deflections are typically measured in the outer wheelpath of the most distressed lane. The maximum spacing for deflection testing shall not exceed 75 m. Consideration will be given to reducing this spacing in urban areas or areas of localized structural failure. In roadway sections of multi-lanes in the same direction, deflections shall be taken in both travel directions. The designer shall use professional judgment to consider additional testing in the other same direction lanes of a multi-lane section if the pavement condition and/or construction history varies significantly. If pre-investigation information indicates the potential for moisture-related damage, consideration should be given to obtaining some cores and/or deflection data in the inside wheelpath.
- **Portland Cement Concrete Pavement:** The deflection testing requirements for Portland cement concrete (PCC) pavement are different than for asphalt concrete pavement and are dependent on the type of PCC pavement. Deflection measurements on PCC pavement are used to determine material properties, load transfer at the joints, and for void detection.
- **Continuously Reinforced Concrete Pavement:** For the determination of material properties related to continuously reinforced concrete pavement (CRCP), testing shall be conducted in the outside wheelpath or between the wheelpaths based on the requirements of the design procedure used. A testing frequency adequate to provide a statistical representation of the material properties along the project is required. Testing at transverse cracks to determine load transfer and the presence of a void shall be considered at cracks that are spalling or are faulted.
- **Jointed Plain and Reinforced Concrete Pavement:** For jointed plain concrete pavement (JPCP) and jointed reinforced concrete pavement (JRCP), deflection measurements are

required to determine material properties, load transfer at the joints, and for void detection. For the determination of material properties, testing shall be conducted in the outside wheelpath or mid slab based on the requirements of the design procedure used. A testing frequency adequate to provide a statistical representation of the material properties along the project is required.

- Composite Pavement: For composite pavements, AC over PCC, the designer shall follow the guidelines in the subsections above based on the type of underlying PCC pavement.

When selecting locations to test in the field, consideration shall be given to the condition of the pavement. Cracks in PCC pavements affect deflections considerably. Every effort shall be made on both CRCP and jointed pavements to take mid-slab / wheelpath deflections at least 2 m from a crack or transverse joint. Transverse cracks are a natural occurrence in CRCP pavements and may be spaced as close as 1 m from each other and still be considered acceptable. Therefore, for CRCP pavements, the above criteria (testing at least 2 m from a crack or transverse joint) is applicable to transverse cracks that are spalled or faulted, longitudinal cracks and punchouts. For jointed pavements, the above criteria apply to all cracking.

Additionally for jointed pavements, consideration shall be given when selecting proposed joint test locations. If joints that are severely spalled, faulted or contain corner cracks or breaks are to be repaired they should not be tested. Joints which are tested and later found to need repair shall not be included in the load transfer and void analysis. The load transfer and void detection procedures were developed for intact slabs (NCHRP Project 1-21, 1985). Therefore, including test results for those slabs being repaired will affect the load transfer factor used in the AASHTO Design Procedure and the resulting overlay thickness, as well as artificially inflating the number of slabs that require undersealing.

### ***Pavement Cores***

Pavement depths are usually determined by either cutting an asphalt concrete (AC) core or from an exploration hole. Cores must be of sufficient size to determine the condition of the pavement layers and crack depths (typically 100 mm diameter core samples). In addition, the designer must consider the requirements of any laboratory testing that may be conducted on cores. If pavement cracking is a concern, the designer shall arrange for some of the cores to be cut through the cracks to evaluate the extent (depth) and severity of the cracking.

Cores are not required for the construction of facilities on a new alignment. .

For the widening of existing facilities, cores shall be taken on the shoulders to determine the depth, type and condition of existing materials.

Pavement depths are required for all pavement rehabilitation projects. The maximum spacing for pavement depth measurements is one core every kilometer for each travel lane or shoulder to be tested. Each core shall be recorded on a core log sheet that includes the following information:

- Project name, roadway name, and segment identification number.

- Location of the core, including the station, direction, lane, and wheelpath
- Date the core was sampled
- Core length
- Depth of individual pavement lifts
- Description of the material characteristics (including depth of materials and visual description)
- If drilled on a crack, the type of crack (fatigue, transverse, etc.) and depth
- Additional Observations such as core delamination, and anything else that might be observed during investigation
- Log must include a drawing showing the location of the core in relation to stripes and pavement edges.

The designer shall include core logs and color photographs of each core with the design report.

### ***Exploration Holes***

Exploration holes are used to gather information about underlying base materials and subgrade soils. Exploration holes must be used where needed to supplement as constructed drawings for base depth, type, and quality and to obtain the necessary information about the materials to adequately characterize their properties for use in the design procedure. Base, soil, and moisture samples can be obtained from exploration holes.

The designer shall submit copies of exploration hole logs and test results with the pavement design report, including the following information:

- Project name, roadway name, and segment identification
- Location of the hole, including the station, direction, lane, and wheelpath
- Depth of material layers
- Description of the material characteristics, plasticity, moisture, soil classification by the Unified Soil Classification System, consistency or density
- If auger probes are performed and advanced through the road pavement, that a split spoon sample should be advanced at the bottom of the probe hole to assist with identifying the strength of the subgrade at that elevation.
- Log must include a drawing showing the location of the hole in relation to stripes and pavement edges

### ***Photographs of Roadway Condition***

Photographs are used to provide a visual record of conditions at the time the investigation is conducted. Photos are suggested for new work sections and are left to the designer's discretion, but are required on all rehabilitation projects. When photographs of the roadway are taken on a given project:

- A maximum spacing of 0.5 km is suggested.
- Photographs shall be taken using a digital camera. Photos must be taken looking in both directions at each location.

- Copies of all photos must be submitted in digital format. Photos must be arranged by station and labeled with the date, station, and direction of the photograph.

### ***Rut Depths***

Rut depths shall be measured on all rehabilitation projects at a maximum of 0.5 km increments. Ruts must be measured in all wheelpaths using a 2 m straight edge.

Measurements must be estimated to the nearest mm. The average rut depth and standard deviation for each wheel track must be reported, and the designer shall submit a summary of the rut measurements in the design report.

### ***Bridge Approaches***

Structures usually present grade control issues for paving projects. Typically, the profile grade at the bridge must be maintained or reduced. Reducing grade normally occurs when asphalt concrete is to be removed from the bridge deck. The following minimum guidelines apply when testing at or near a structure:

- For structures with AC on the deck, the designer shall obtain at least one core at approximately the mid-span (through the AC only, do not core through the concrete deck).
- If existing approach consists of AC pavement, obtain two cores on each bridge approach at approximately 3 m and 15 m from each end of the structure or approach slab (do not core on the approach slab).
- The designer shall perform deflection testing at 1.5, 3, 5, 10, 15, 20, 25, 30, 40, 50, and 60 m from each end of the structure.
- Coring shall not be performed on a bare Portland Cement Concrete (PCC) deck.

If the bridge approaches are to be replaced, the above testing is not required. However, if the pavement designer is to evaluate possible rehabilitation strategies in lieu of reconstruction, the above testing is required.

### ***Bridge Underpasses***

Another grade control area is under structures that cross over the highway. If the existing vertical clearance is substandard, additional testing of the pavement similar to that completed for bridge approaches should be completed.

### ***At-Grade Railroad Crossings***

Railroad crossings pose a grade control situation, in that the existing grade must be maintained. The designer shall not perform any testing on railroad ROW without railway supervision. The pavement designer shall contact the railroad company to obtain information on underground facilities and to coordinate safety and operational issues for any work within the area of the crossing. The following minimum guidelines apply when testing at or near an at-grade railroad crossing:

- If existing approach consists of AC pavement, the designer shall obtain two cores on each approach at approximately 3 m and 15 m from the stop bar.
- Deflection testing at 1.5, 3, 5, 10, 15, 20, 25, 30, 40, 50, and 60 m from the stop bar.
- Testing between railroad gates or stop bars shall not be performed without railway supervision

### ***Pavement Distress Surveys***

Pavement distress surveys are an integral part of a successful pavement rehabilitation project. Pavement distresses are defects in the pavement surface such as ruts and cracks. Proper distress identification helps the designer determine the mode of failure such as, whether the distress is due to load related factors or environmental effects. In addition, the distress surveys help the designer develop the field investigation plan, determine if reflective cracking will be a factor in the rehabilitation performance, and are a primary factor in identifying areas that require localized repairs. When combined with other data collected on a project such as cores and deflections, distress surveys are very important in assessing the pavement rehabilitation needs.

The City has adopted pavement distress definitions based on the ASTM D6433-12: *Standard Practice for Roads and Parking Lots Pavement Condition Index Surveys* for both network and project level pavement distress surveys. The minimum information required in a distress survey includes:

- Type of distress
- Severity of distress
- Extent of distress
- Location of distress.

For asphalt concrete pavement and CRCP, a simple form may be used. For reinforced and plain concrete pavements with joints, the designer shall create a crack map for conducting the distress survey. The crack map allows the designer to identify and locate distresses in individual slabs. This information can be used later in determining repair and undersealing quantities, as well as for marking the repair areas in the field.

### **2. Laboratory Investigation**

Laboratory testing shall be used to supplement the field investigation and to evaluate material samples collected in the field. Laboratory testing shall not replace field investigation unless absolutely necessary. An example might be a new alignment where no roadway currently exists and normal roadway investigation practices are not possible.

### ***Laboratory Tests***

Laboratory testing of materials may include (but are not limited to) the following:

- Existing HMAC (Hot-mix asphalt concrete): Void content, bulk & theoretical maximum density (rice), indirect tensile strength, susceptibility to stripping
- Existing aggregate base: Gradation, moisture / density and moisture content

- Existing subgrade: Classification, Atterberg Limits, moisture / density, resilient modulus, natural moisture content.

The condition of asphalt core samples can be compared based on percent density. The asphalt lift(s) of interest can be tested for bulk specific gravity, and the maximum theoretical density can be obtained from construction records or by performing AASHTO T-209. The strength of asphalt core samples can be compared based on the as-received (unconditioned) indirect tensile strength value. The asphalt lift(s) of interest are tested for indirect tensile strength according to AASHTO T-283.

### ***Testing Frequency***

The frequency of laboratory testing of existing materials for any given project will be dependent on the specific needs of that project. A minimum of 25% of boreholes are to be tested. Factors to be considered when determining the need for or extent of laboratory testing may include (but are not limited to) the following:

- Low confidence level in field investigation test analyses as a result of unexplainable variability or deviation from normally accepted values
- Project locations that are not conducive to on-site field testing
- Verification of marginal or borderline field test results
- Analysis of material properties which are non-testable in the field.

## APPENDIX C

# RECOMMENDED PAVEMENT MINIMUMS



