(DRAFT) 2+1 ROADWAY PILOT PROJECT SITE SELECTION AND DESIGN PARAMETERS REPORT

2+1 Site Selection Provincial List Team

December 2021

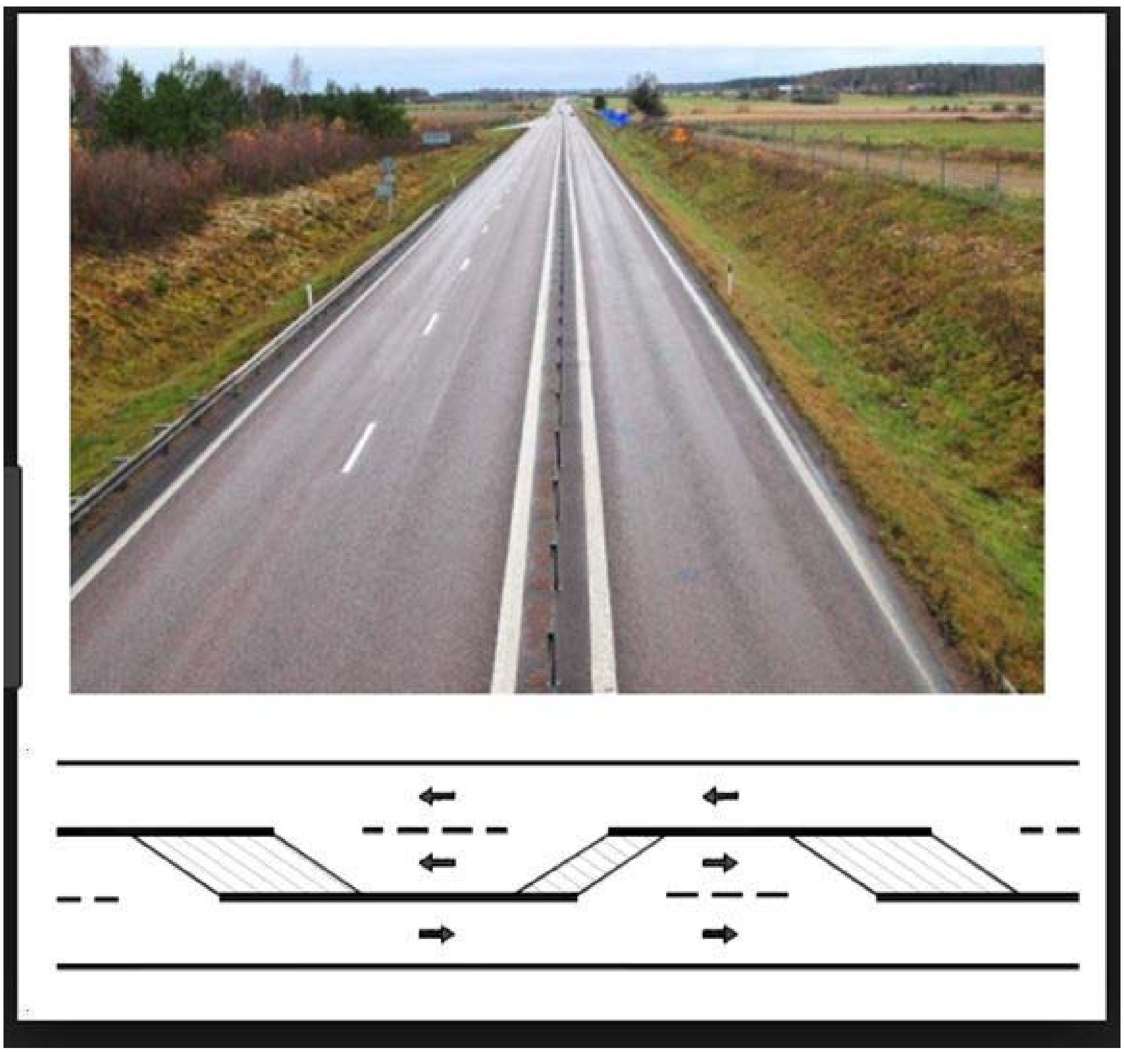
Ontario

Table of Contents

2+1 Pilot Site Selection
Executive Summary

A 2+1 roadway model consists of a three-lane cross-section with one lane in each direction of travel and an additional third lane alternating between directions. The design also typically includes a flush narrow median and median barrier. This design has been implemented in jurisdictions in Europe and Scandinavian countries where it has been shown to reduce crossover collisions and enhance capacity due to the median barrier because it allows for faster moving vehicles to pass slower vehicles at regular and frequent intervals .

The Ministry of Transportation Ontario (MTO) formed a 2+1 Advancement Working Group to research 2+1 roadway models and develop a variation of the model appropriate for Ontario highways.



Using the parameters and criteria established as set out in the 2+1 Site Selection Criteria Report (September 2021), each of the Ministry of Transportation provincial offices were presented with an overview of a 2+1 roadway model, the history of its development and the process for establishing a list of potential 2+1 roadway pilot locations in Ontario. Instruction on how to use a 2+1 Feasibility Table contained within the Site Selection Report and an overview of the scoring process was also provided.

The scoring process contained an initial screening that included a pass / fail selection to identify locations not suitable for further investigation. Remaining locations were scored through individual criteria under each parameter. The scoring for each criterion was from 1 to 3, with 1 as the lowest, and 3 as the highest score.

After each office had scored their proposed 2+1 pilot locations, a list of the top 5 candidate locations across the province was established based on the highest scored locations. These locations underwent a further review of both the preliminary cost estimate per kilometre to construct, the overall benefit-cost and stakeholder considerations.

The results of the initiative produced the following top two (2) locations:

1. Highway 11 from Sand Dam Road to Ellesmere Road
2. Highway 11 from Hwy 64 to Jumping Caribou Lake Road

Further analysis through a preliminary design report and associated Environmental Assessment will be required after which a final decision on the pilot site location will be determined.

1.0 Background

In 2018, MTO conducted a feasibility study regarding the implementation of the 2+1 roadway concept as part of an Operational Performance Review (OPR) for a section of Highway 11 between North Bay and Temiskaming Shores. This study revealed concerns related to the type of median barrier typically used, as well as conflicts between design parameters and standards of international jurisdictions that have used 2+1 roadway models, and MTO design standards and parameters, at that time.

In 2020, MTO developed a 2+1 Advancement Working Group to further research 2+1 roadway models and to develop a variation of the model appropriate for Ontario highways.

The information gathered in the first phase was used to develop a mission statement for the Working Group:

“To develop a 2+1 highway model applicable for Ontario that will provide a cost-effective means of enhancing overall safety and efficiency of highways while

supporting highway maintenance. As part of this, we will develop a priority list of locations for a 2+1 highway type in Ontario that would have the best potential building on the experience of others and building public confidence. The site will be monitored to determine the benefits derived from the application."

This mission statement provided clear objectives for the group as the workshop phase of the project commenced.

The working group developed the 2+1 Site Selection Criteria Report that outlined the parameters, criteria, and associated scoring to be used in reviewing candidate sites suitable for piloting the 2+1 model. The draft 2+1 Site Selection Criteria Report was posted on the Ministry's Technical Consultation Portal on Monday September 13, 2021 for three weeks. The report was viewed 130 times and no comments were submitted.

Following this work, a list of three to five candidate locations within each Program Delivery Office area, were run through the selection criteria and scored by staff in the area. Prior to this step, background documents, feasibility calculation tables and samples for the criteria selection process had been shared with these staff members.

2.0 2+1 Pilot Selection Provincial List Team

The staff which identified and evaluated the 2+1 pilot locations throughout the province are:

- Robert Long, Team Lead, MTO Supervisor Traffic Section, North Bay Office
- Emily Alexander, MTO EIT, Transportation Infrastructure Management, Thunder Bay Office
- Heather Hansen, MTO Supervisor Traffic Section, London Office
- Matthew Fabiilli, MTO Project Engineer Transportation Infrastructure Management, London Office
- Liz Lindensmith, MTO EIT, Traffic Section, Kingston Office
- Lori Brake, MTO Supervisor Traffic Section, Kingston Office
- Venetia Stephen, MTO Traffic Analyst Traffic Section, Downsview Office
- Jananan Muththalagan, MTO EIT Traffic Section, Downsview Office

3.0 Selection Criteria

The site selection parameters / criteria were outlined in the 2+1 Site Selection Criteria Report. They were developed to aid in the identification of pilot project locations. The list below summarizes the parameters developed which were used in the identification of a list of potential 2+1 pilot locations for the entire province.

1. Traffic Operating Characteristics
2. Existing Highway Safety Performance
3. Centreline Barrier and Minimizing Barrier Drops
4. Minimize Widening Issues
5. Reduce or Eliminate Adjacent Traffic
6. Operating Considerations
7. Geometric Standards

4.0 Site Selection

The seven parameters and corresponding criteria, utilized in the site selection process, are shown in the 2+1 Feasibility Calculation Table in Appendix A.

Each of the five Program Delivery offices across the province was tasked with identifying three to five potential 2+1 pilot sites within their regional area to be analyzed against the criteria.

The process involved a four-step pass/fail screening procedure that allowed ministry staff to determine which sites would not be a good fit for a 2+1 pilot location. If one of the initial pass/fail criteria was not satisfied, the location was removed from the list and not reviewed further.

The first step considered whether a site met a warrant for a passing lane(s) or truck climbing lane; does the location under consideration include an existing passing lane(s) or truck climbing lane or is it a 4-lane holding strategy? If one of these conditions was met there was justification for evaluating the location using the next criteria.

The next pass/fail criterion included reviewing the highway segment to determine if there was adjacent traffic such as horse and buggy and/or agricultural equipment which travel along the highway segment. The existence of these vehicle types within a trial location, would potentially create safety issues within the single lane highway segments where slow-moving vehicles might infringe into a high-speed lane. If there was adjacent traffic as noted above, the location was removed from further consideration.

The final two pass / fail criteria included truck inspection stations and railway crossings. If either of these conditions existed within a potential 2+1 roadway pilot location, the location was removed from further consideration. If a location passed each of the pass/fail criteria, it stayed on the list of potential sites for further evaluation.

In the next step, details for each location that passed the initial screening process was documented. The details included identifying the highway, a description of the highway segment and endpoint reference points as determined through Linear Highway Reference System (LHRS) and township description. This documentation allowed for further investigation through collision and volume data, identification of the highway speed as well as research specific to the inventory of the items that were to be noted to complete the scoring. These items included the number of intersections and entrances per 5 km sections and the number of structures (bridges) and structural culverts throughout the entire section.

Local terrain as well as the complexity of grading within a given section of highway was another item requiring a desk top review to identify the scope (severity) of the work that would be required to implement the pilot site.

Further criteria that was considered included the proximity of a potential 2+1 pilot site to a patrol yard and the cost of additional equipment required to maintain the pilot location on a yearly basis.

Geometric standards were also considered in the rating. The number of substandard horizontal curves at the end of a 6% or greater downgrade and minimum and maximum horizontal and vertical curves found within a potential pilot location were documented.

The rating system for each of these above-noted criteria is prescribed in the 2+1 Pilot Selection Criteria Report with rankings from 1 through 3, with 1 as the lowest score and 3 as the highest.

5.0 Potential 2+1 Pilot Locations

Once the locations were screened and the selection criteria were scored for each location, the results were compiled and listed in Table 1 below. Table 1 provides a description of each location analyzed which is then broken down by areas within the province and otherwise shown in no specific order. The scores established through the application of the criteria outlined in the 2+1 Feasibility Calculation Table as shown in Appendix A are noted in the right most column of the table. The highest obtainable score is 3. A summary of all the information provided for each site evaluated is contained in Appendix B.

The initial pass / fail screening for the four sites identified in southwestern Ontario resulted in the elimination of all four sites. The screening was completed on two locations identified on Highway 10, one on Highway 26 and one on Highway 40. Due to the nature of the use of the land and plentiful farmland within the area, no locations passed the criteria for “No Adjacent Vehicles (Agricultural or Horse Drawn Vehicles).”

As such the southwestern site selections were removed from consideration as noted in the table below.

Table 1: 2+1 Provincial Site Selection List

Highway	Description	Section Length	Score
Hwy 17	200m West of Jocko Point Road to Sandy Falls Road (**Sturgeon Falls Area**)	8.3km	2.00
Hwy 17	Region Road 55 (East Junction) to start of 4 lanes at Hwy 69 (**Sudbury Area**)	11.0km	2.13
Hwy 17	Hwy 69 to start of 4 lanes divided (Junction Creek) **(Sudbury Area)**	11.5km	2.03
Hwy 11	Sand Dam Road to Ellesmere Road (**North Bay Area**)	13.8km	2.35
Hwy 11	Tilden Lake Road North to Martin Lake Road (**Tilden Lake Area**)	14.1km	1.92
Hwy 11	Hwy 64 to Jumping Caribou Lake Road (**Temagami Area**)	16.3km	2.38
Hwy 17	1500m N of Round Lake Road to 430m South of Paquette Road (**Petawawa Area**)	14.1km	2.21
Hwy 17	230m North of Paquette Road to 200m South of Clouthier Road (**Petawawa Area**)	12.0km	2.31
Hwy 17	Algoma / Thunder Bay Boundary to White River Bridge (**White River Area**)	12.4km	1.99
Hwy 17	Overhead Mine Tailings Line to Lecours / Pic Township Boundary (**Marathon Area**)	17.5km	2.00
Hwy 11	700m N of Radio Tower Road to 18.64kn South of Hwy 580 **(Macdiarmid Area)**	12.0km	2.13
Hwy 9	Heart Lake Road to 530m West of Concession Road 5 (**Orangeville Area**)	12.7km	2.35
Hwy 26	Centreline Road to West of Sideroad 15&16 (**Stayner Area**)	9.2km	2.53

Locations Considered but did not pass Criteria

Hwy 10	200m South of 170 Road to 550m North of County Road 32 (**Flesherton Area**)	6.8km	
Hwy 10	600m North of Side Road 30/ Chatsworth Road 24 to 425m South of Grey Road 40 (**Holland Centre Area**)	7.7km	
Hwy 26	500m West of Grey Road 112 to 400m West of Grey Road 15 (**Meaford Area**)	18.0km	
Hwy 40	Wallaceburg to Sarnia (**Sarnia Area**)		

6.0 Selection of the Top 5 2+1 Pilot Locations

Once the provincial list was completed, the score for each of the sites were ranked to establish the five highest ranking locations within the province.

The Advancement Working Group reviewed and confirmed the rankings of the top 5 locations. Based on the parameters and criteria scoring, the ranking is:

1. Highway 26 from Centreline Road to West of Sideroad 15&16
2. Highway 11 from Highway 64 to Jumping Caribou Lake Road
3. Highway 9 from Heart Lake Road to 530 West of Concession Road 5
4. Highway 11 from Sand Dam Road to Ellesmere Road
5. Highway 17 from 230m North of Paquette Road to 200m South of Clouthier Road

7.0 Benefit Cost Evaluation

Once the top five locations were determined, further analysis was required to establish a ranking which also considered the estimated construction cost and benefit derived from the implementation of the model.

A process that considered the grading complexity and the percent of existing passing lane within a given highway segment proposed was used to establish the construction cost per kilometre. This value was used in conjunction with the Safety Analyst program to derive the safety benefit of the installation of the 2+1 model.

The construction cost considerations included an estimated price per kilometre based on a desk top exercise to determine the anticipated complexity of the soils in each candidate location. In consultation with geotechnical section in the area of the location, the soils were ranked according to complexity, with 1 being high complexity (poor) soils and 3 being good soils. For a soil complexity score of 1, the estimated cost of construction is $2.0 M per km, for a soil complexity score of 2, it was $1.5M per km and for a soil complexity score of 3, $1.0M per km. The per km cost associated with upgrading an existing 3 lane section was $500,000. It should be noted that an independent analysis was carried out by the Design Standards Office that confirmed the above analysis to be reasonable.

The Safety Analyst software utilizes Collision Modification Factors (CMFs) to establish the benefit cost ratio. For the purpose of this review and for consideration of the various crash types, 3 different CMFs were utilized for "*install cable median.*" Although the barrier to be installed will not necessarily be cable, these CMFs are considered relevant and will capture the pertinent information. These CMFs are found within the MTO CMFs Manual.

The first CMF relates to rear end and sideswipe collisions where cable median has been installed. The second CMF relates to fixed object, run off road and single vehicle collisions, while the third CMF considered cross median, frontal and opposing direction collisions.

When each CMF was run for a single highway section, the sum of the 3 different CMFs was averaged to establish the Safety Benefit. This combined with the estimated construction cost per kilometre, established the benefit cost. The benefit cost was then utilized to prioritize the top five 2+1 roadway pilot site selection list. The summary results of each analysis are shown in Table 2.

Table 2: 2+1 Cost and b/c

Highway	Description	Cost/km/M	b/c
Hwy 17	230m North of Paquette Road to 200m South of Clouthier Road	$0.9	0.12
Hwy 11	Sand Dam Road to Ellesmere Road	$1.0	0.08
Hwy 11	Highway 64 to Jumping Caribou Lake Road	$1.3	0.06
Hwy 26	Centreline Road to West of Sideroad 15&16	$1.5	0.31
Hwy 9	Heart Lake Road to 530m West of Concession Road 5	$0.9	0.35

8.0 Other Considerations

The 2+1 Site Selection Criteria Report acknowledged that a review of the sites would be necessary to consider those things not identified by the criteria alone, such as entrance density and potential stakeholder impacts.

An overview of the evaluations for all the sites selected was presented to the 2+1 Advancement Working Group for further discussion regarding observations and features noted around each of the top five locations. The highway sections on Highway 26 and Highway 9, although scoring well overall against the criteria, had approximately 40 and 50 entrances and 15 and 4 intersections over 13 km and 9 km segments respectively. Given the high number of entrances and intersections, these locations were deemed to be impractical for advancement of the 2+1 model.

Subsequent discussions concerning Highway 17 in the Petawawa area, revealed that the location is surrounded by Department of National Defense (DND) lands. Consideration of the potential for adjacent travel by armored vehicles combined with process of acquiring approvals required from DND when seeking to make changes to the highway, made this location impractical for the advancement of a pilot location.

Based on the foregoing, the following highway sections were identified as the top 2 potential pilot locations:

1. Highway 11 from Sand Dam Road to Ellesmere Road

2. Highway 11 from Hwy 64 to Jumping Caribou Lake Road

A Preliminary Design Report and associated Environmental Assessment will be required to provide the additional analysis necessary to move this project forward toward the design phase.

9.0 Design Parameters

The 2+1 roadway concept is new to Ontario. As 2+1 roadways are typically used to improve conditions on existing two-lane rural highways with relatively high volumes of traffic, design parameters for 2 lane King's undivided highways were used as the starting point to develop standards applicable to the model. The design parameters to be considered for the design of 2+1 roadway facilities are included in Appendix C.

Appendix A

2+1 Feasibility Calculation Table

<table>
<tr><td rowspan="9">Location Information</td><td colspan="2">Region</td><td></td></tr>
<tr><td colspan="2">Highway</td><td></td></tr>
<tr><td colspan="2">Length (km)</td><td></td></tr>
<tr><td rowspan="3">Starting Location</td><td>Township</td><td></td></tr>
<tr><td>LHRS</td><td></td></tr>
<tr><td>Description</td><td></td></tr>
<tr><td rowspan="3">Ending Location</td><td>Township</td><td></td></tr>
<tr><td>LHRS</td><td></td></tr>
<tr><td>Description</td><td></td></tr>
<tr><td>Parameter</td><td>Criteria</td><td>SCORE</td><td>Comment</td></tr>
<tr><td>Traffic Operating Characteristics</td><td>Passing Lanes / Truck Climbing Lanes Warrant</td><td>PASS/FAIL</td><td></td></tr>
<tr><td>Reduce or Eliminate Adjacent Traffic</td><td>Horse Drawn Vehicles or Agricultural Vehicle Traffic</td><td>PASS/FAIL</td><td></td></tr>
<tr><td>Proximity to Maintenance Amenities</td><td>Location Free of Truck Inspection Stations and or Motor Vehicle Inspection Stations</td><td>PASS/FAIL</td><td></td></tr>
<tr><td>Railway Crossings</td><td>At-Grade Railway Crossing(s) Present</td><td>PASS/FAIL</td><td></td></tr>
<tr><td rowspan="3">Traffic Operating Characteristics</td><td>Posted Speed</td><td></td><td></td></tr>
<tr><td>Volume</td><td></td><td></td></tr>
<tr><td>Warrant / Existing / Intermediate Step for 4 Laning</td><td></td><td></td></tr>
<tr><td>Reduce or Eliminate Adjacent Traffic</td><td>Cycling Traffic</td><td></td><td></td></tr>
<tr><td>Existing Highway Safety Performance</td><td>Intermediate Steps Taken (Trial of Lesser Options)</td><td></td><td></td></tr>
</table>

	Total Number of Expected Equivalent Property Damage Only (EPDO) Collisions		
	Collision Impact Type		
	Wildlife Collisions		
Barrier Drop Parameters & Potential Widening Issues	Minimize Intersections		
	Minimize Entrances		
	Minimize Structures (Bridges)		
	Minimize Structural Culverts		
	Minimize VMS/ RWIS		
	Complexity of Grading		
Proximity to Maintenance Amenities	Proximity of Patrol Yard		
	Availability of Compliant Required Equipment		
Geometric Standards	Horizontal Alignment (substandard at end of downgrades) (Maximum Grades)		

Appendix B

Evaluation Summary

Location Information							Traffic Parameters			
Region	Highway	Length (km)	Starting Location Township	Starting Location Description	Ending Location Township	Ending Location Description	Posted Speed km/h	Volume AADT 2021	Passing Lanes / Truck Climbing Lanes Existing or Warranted	Intermediate Step for 4 Laning
NW	17	12.4	Knowles	Algoma/Thunder Bay Boundary	McCron	White River Bridge - Bremner	90	1943	Yes	No
NW	17	17.5	Bomby	Overhead Pipes	Lecours	Lecours/Pic Boundary	90	2468	Yes	No
NW	11	12	Kilkenny	18.64 km S of Hwy 580	UT 493875	TCPL & FOTS Crossing	90	1514	Yes	No
Central	9	12.7	East of Orangeville	Heart Lk Rd		West of Ballycroy (Conc 5)	80	16000	yes	
Central	26	9.2	Sunnidale	West of Stayner	Sunnidale	West of Sideroad 15&16	80	11500-13200	yes	
East	17	14.12	Petawawa	430m S of Paquette Rd	Alice	CNR overpass	90	8200-9400	yes	no
East	17	12	Petawawa	230m N of Paquette Rd	Buchanan	450m S of Clouthier Rd	90	7500-7780	yes	no
NE	17	8.3	West Nipissing	200m W of Jocko Point Road	West Nip	Sandy Falls Road	90	9200	yes	no
NE	17	11	Sudbury	RR 55 East Junction	Sudbury	start of 4 lanes (Hwy 69)	90	8700		yes
NE	17	11.54	Sudbury	Hwy 69	Sudbury	Start of 4 lan divided(Junction Ck)	90	8000-12800		yes
NE	11	13.8	Merrick	Sand Dam Rd	Notman	Ellesmere Rd	90	3500-4700	yes	no
NE	11	14.1	Lyman	Tilden Lake Rd	Gladman	Martin Lake Rd	90	3500-4300	yes	no
NE	11	16.3	Sick	Hwy 64	Olive	Caribou Lake Rd	90	3400 to 4150	yes both	no

Existing Highway Performance Parameters				Barrier Drop Parameters & Potential Widening Issues						Adjacent Traffic Issues	
Excess Collisions In Locations	Collision Type Approach / SS	Over representation of Sideswipe/ Cross Over Collisions	Less Invasive Safety Improvement Options Investigated	Number of Entrances in Segment	Number of Intersection in Segment	Number of VMS/ RWIS/ Overhead Signage Installations	Number of Bridges in Segment	Number of Structural Culverts in Segment	Comlexity of Grading	Segment located on Provincial Cycling Network?	Slower Moving Traffic on Shoulders (ie. Horse and Buggy/ Agricultural Equipment)
0.143	8 (26%)	Yes	No	13	0	0	0	2	3	Yes	No
0.143	11 (20%)	Yes	No	6	2	0	0	0	2	Yes	No
0.143	3 (19%)	Yes	No	4	2	0	0	1	3	Yes	No
0.429	94 (16%)	yes	yes	~40	15	0	(3)	(1)	2	no	Farm Equipment?
0.429	89 (17%)	yes	yes	~50	4	0	(3)	(1)	2	no	Farm Equipment?
6.052	5.10%	no	yes CL rumble	0	4 avg 1.39/5k	1 rwis	1	1	3	no	no
5.74	3.30%	no	yes CL & edge rumble	1	4 avg 1.67/5k	1 rwis	1	1	3	no	no
6.57	0.00%	no	yes cl rumble	5 per 5km	3 over 5km	0	0	0	2	yes	no
7.4	8%	no	yEs Cl & edge Rumble	1 snwtrnarnd	0	0	1	2	1	no	no
7.8	9.20%	no	yEs Cl & edge Rumble	0	2 per 5km	1	2	1	1	no	no
3.2	10%	yes	yes CL rumble	4 per 5km	3 over 13km	0	0	1	2	no	no
3.32	7%	no	yes CL rumble	3 per 5km	6 over 14km	0	0	0	2	no	no
3.2	11.80%	yes	yes CL rumble	4 per 5km	2 per 5km	0	0	1	1	no	no

Equipment Availability	Maintenance Parameters	Geometric Parameters		Stakeholders
	Maintenance Response Time for Segment	Number of substandard or minimal radii for Horizontal and Vertical Curves in Highway Segment	Number of substandard Grade location in Highway Segment	List All known stakeholders within the highway segment (ie. Utilities, Municipalities, First Nation Communities, Rail Authorities, Trail Federations etc.)
Equipment Required	45 minutes	20	1	None known
Equipment Required	15 minutes	13	1	HydroOne (hydro line crossing), Hemlo Mine (pipe crossing)
Equipment Required	10 minutes	4	0	TransCanada (natural gas pipeline crossing), HydroOne (hydro line crossing), Sand Point FN, Municipality of Greenstone
(2)	<1hr	(3)	(3)	
(2)	<1hr	(3)	(3)	
minimal additional equip	20min	none	none	
minimal additional equip	20min	none	none	
equipment available	<1hr	none	none	
equipment available	<1hr	1	none	
equipment available	<1hr	none	none	
equipment available	<1hr	1	none	
significant equipment required	1 to 2hr	none	none	
significant equipment required	1 to 2hr	2	0	

Appendix C

Design Parameters Report

2+1 Roadway Design Parameters Report

November 2021

STANDARDS AND CONTRACTS BRANCH
HIGHWAY DESIGN OFFICE

Table of Contents

1. Introduction

Geometric design standards are based on the function for different highway classes. There are 40 highway classes in the functional classification for the provincial highway network. Design standards for the existing highway classes will be used as the starting point and maintained wherever possible. However, standards for the 2+1 roadway may require adjusting to balance driver expectations, safety, and costs.

The following is based on a 2+1 roadway concept being used on an existing section of highway. As such, the scope of work required to build a 2+1 roadway section should be expansion or full reconstruction. Both expansion and full reconstruction typically require that highway elements meet standards. The design exception process is to be followed where it is not possible or economically feasible to meet standards.

Some highway elements related to 2+1 roadways allow the use of design domains. In addition to the design exception process, design domains provide flexibility for the selection of the appropriate standard by defining minimum and desirable values. While expansion and full reconstruction projects should aim at meeting desirable standards, site specific conditions may justify the use of minimum standards.

For design guidelines and highway elements not explicitly identified in this document, existing ministry policies, directives and guidelines shall be used. The Highway Design Office should be consulted for deviations from minimum standards prior to triggering the scope exception process.

2. Report Organization

This report was prepared following the order as described in the Design Criteria template and guidelines. While not all Design Criteria parameters and highway elements are listed, the sections below present and discuss selected parameters that are most relevant for the design a 2+1 roadway section.

Project specific information, including but not limited to highway number, location information, project length, Group Work Project number, and list of signatories are not discussed in this document.

3. Asset Work Type

The asset work type reflects the scope of work for projects on provincial highways. Building a 2+1 roadway cross-section and associated work, including intersection improvements and realignments, should be considered New (expansion) or Replace (reconstruction).

4. Functional Highway Classification

The functional highway classification system relies on balancing access and mobility. The Functional Highway Classification is derived from combinations of the following criteria:

- Urban (U) or Rural (R);
- Divided (D) and Undivided (U);
- Local (L), Collector (C), Arterial (A) or Freeway (F); and
- Design Speed (from 40 km/h to 120 km/h)

Exhibit 2-G of the April 2020 MTO Design Supplement presents the framework for the 40 highway classes used on provincial highways, ranging from Urban Local Undivided, 40 km/h Design Speed (ULU 40) at its lowest class, to Rural Freeway Divided, 130 km/h Design Speed (RFD 130) at its highest.

2+1 roadways are typically used in rural areas with relatively high volumes of traffic. The use of median barriers restricts access to and from properties, which is not desirable in an urban context. From the perspective of land use and density of development, 2+1 roadways should be classified as rural facilities.

The 2+1 roadway includes a narrow median and a flexible or semi-rigid median barrier to divide the two directions of travel. As 2+1 roadways introduce a narrow median to separate the two directions of travel, they could be considered divided. It is however recognized that the 2+1 roadway concept does not perfectly fit within the existing classification, especially with respect to the introduction of a narrow flush median or buffer area to separate directions of travel. Traditionally, MTO has reserved the divided classifications for roadway sections with a physical barrier and grouped narrow flush medians in the undivided category. Due to the conversion from existing facilities and the surface drainage characteristics, 2+1 roadways should be primarily based on parameters for undivided classes of highways.

With respect to highway use, 2+1 roadways should not be classified as freeways or local. Collector and arterial classes may be considered for 2+1 roadways.

With respect to design speed, 2+1 roadways improve safety and operations on existing high-speed highways (design speeds 70 km/h and higher). Posted speeds are typically 20 km/h lower than design speeds. While there may be merit in considering sections with 80 km/h and 90 km/h design speeds, the 2+1 roadway concept should be designed with 100 km/h or 110 km/h design speeds.

The following criteria are excluded from further consideration: all highways in built-up areas, all freeways and local highways, all traditional divided highways, and all highways with design speeds lower than 100 km/h.

The following three functional classes should be considered when designing a 2+1 roadway section of highway:

- RAU 110
- RAU 100
- RCU 100

The highway elements discussed in the sections below reflect values for 100 km/h and 110 km/h design speeds.

5. Minimum Stopping Sight Distance (m)

Stopping sight distances should be selected for the appropriate design speed of an undivided King's highway. For a design speed of 100 km/h, the minimum stopping sight distance is 185 m. For a design speed of 110 km/h, the minimum is 220 m.

6. Crest: Minimum "K" value

Crest curves should be selected for the appropriate design speed of an undivided King's highway. For a 100 km/h design speed, the minimum Crest K value is 60. For 110 km/h, the minimum is 80.

7. Sag: Minimum "K" value

Sag curves should be selected for the appropriate design speed of an undivided King's highway. For a 100 km/h design speed, the minimum Sag K value is 45. For 110 km/h, the minimum is 60.

8. Grades Maximum (%)

Grades should be selected for the appropriate design speed of an undivided King's highway. For a 100 km/h design speed, the maximum grade is 6 – 8%. For 110 km/h, the maximum grade is 6 – 7%.

9. Minimum Radius (m)

Radius should be selected for the appropriate design speed of an undivided King's highway. For a 100 km/h design speed, the minimum radius is 450 m. For 110 km/h, the minimum is 600 m. However, the designer should also consider the discussion in section 19 about the effect of barrier on sight lines on horizontal curves.

10. Lane Widths (m)

Lane widths should be selected for the appropriate volumes and design speed of an undivided King's highway. The three lanes should be of the same width.

For the 100 km/h and 110 km/h design speeds being considered, lanes are recommended to be 3.75 m wide with the following exceptions, where 3.5 m lanes are acceptable:

- 100 km/h design speed, AADT from 3,000 vpd to 4,000 vpd and percent commercial less than 10%, and
- 100 km/h design speed, AADT from 2,000 vpd to 3,000 vpd and percent commercial less than 15%.

11. Shoulder Width, Left (m)

The TAC-GDG, as modified by the MTO Design Supplement, recommends 1 m left side shoulders be used on 4-lane divided highways. On multi-lane divided freeways, the left shoulder width is 2.5 m or according to the type of barrier used.

Refer to #14 Median Width below for further left shoulder analysis.

12. Shoulder Width, Right (m)

The MTO Design Supplement requires that, on 4-lane divided highways, right shoulders be the same as for undivided highways. Section 4.4.2 of the MTO Design Supplement includes shoulder width guidance.

Right shoulder width should be selected for the appropriate design speed of an undivided King's highway. For the 100 km/h and 110 km/h design speeds being considered, shoulder is recommended to be 2.5 m wide with the following exceptions, where 3.0 m shoulders are required:

- Design speed of 110 km/h, AADT > 3,000 vpd, and % commercial greater than 10%;
- Design speed of 100 km/h, AADT > 4,000 vpd and % commercial greater than 10%.

13. Shoulder Rounding (m)

The Roadside Design Manual (RDM) introduces the concept of design domain for shoulder rounding. The design domain includes desirable and minimum values for rounding width.

For design speeds 100 km/h or greater, the desirable and minimum rounding widths are 1.5 m and 1.0 m respectively.

The RDM states "Providing desirable rounding widths on Major expansion and Reconstruction Projects should accommodate future increases in top of pavement grade due to pavement overlays and/or pavement recycling, therefore minimizing subsequent need to reduce shoulder widths." At the same time, consideration should be given to the fact that the 2+1 Roadway cross section will be mainly built on an existing alignment by widening as appropriate to meet the required standards of the different highway elements.

It is recommended that the desirable rounding width of 1.5 m be included as part of the widening to build the 2+1 Roadway cross section.

14. Median Width (m)

The 2+1 Roadway cross-section is based on a flush narrow median without a median drainage system.

The following was considered for the identification of design domains for narrow medians on 2+1 roadways:

- The MTO Design Supplement defines median as follows:

  "The area that laterally separates traffic lanes carrying traffic in opposite directions. A median is described as flush, raised or depressed, referring to the general elevation of the median in relation to the adjacent edges of traffic lanes. The terms wide and narrow are often used to distinguish different types of median. A wide median generally refers to depressed medians sufficiently wide to drain the base and subbase into a median drainage channel. Flush and raised medians are usually narrow medians."

- Section 4.5.1 'Technical Foundation' for Medians and Outer Separations of the TAC-GDG states:

  "Median width is the lateral dimension measured between the inner (left) edges of the travelled lanes and includes the left shoulder, as well as the gutter or offset widths…

  "A median is a safety device which provides some measure of freedom from interference of opposing traffic… Medians add to a sense of open space…

  "Median widths may be as narrow as 1 m and as wide as 30 to 35 m."

- Section 4.5.3 'Arterial Road Medians: Application Heuristics' of the TAC-GDG states:

  "1.A flush median without barrier may be appropriate for rural highways with low to medium volumes and operating speeds. This median is normally slightly crowned to effect drainage, and is normally paved, often in the same surface material as the adjacent lanes. It is advantageous, however, to surface the median in a contrasting texture and/or colour to alert the errant driver travelling in the median. Widths of flush highway medians without median barriers can vary between 1.0 m and 4.0 m.

  "2.Wider flush medians with barriers normally apply to high speed rural arterial roads…"

- Section 4.4.2 of the MTO Design Supplement requires left (median) shoulder width to be 1 m minimum per direction on 4-lane divided highways. This 1 m minimum shoulder width may be part of the grass median, typical of 4-lane rural highways.

- Section 4.4.2 of the MTO Design Supplement recommends a minimum usable shoulder width of 2.0 m to accommodate a disabled vehicle.

- Shy lines: As defined in the RDM, shy line is defined as the distance between the edge of the driving lane to the inside edge of a barrier system. The recommended minimum shy line offsets are 2.8 m for 110 km/h and 2.4 m for 100 km/h design speeds. Refer to the RDM for a complete description and minimum values for different design speeds.

- Barrier deflection: The RDM recommends that "Semi-rigid and flexible barrier systems should only be used if there is a sufficient working width provided between the traffic face of the system and the obstacle beyond the back of the system to accommodate dynamic deflection under the specified design impact. If the barrier system is placed too close to the obstacle, the impacting vehicle can deflect the barrier system into the obstacle, allowing the vehicle to interact with the obstacle."

- Barrier deflection guidelines in the Manual for Assessing Safety Hardware (MASH): Section 5.2.1 Structural Adequacy states "A barrier's working width is therefore measured and reported as a means for allowing highway designers to avoid placing a barrier too near an obstruction." A vehicle traveling in the opposite direction is an obstruction that should be beyond the barrier's working width.

- Optimization: 2+1 roadways are used by many jurisdictions outside of North America. The concept was initially developed to retrofit existing facilities. 2-lane cross-sections turned into 3-lane facilities within the existing footprint. Only localized widening would be carried out, more associated with access than cross-section needs. Lane and right shoulder widths would be reduced to accommodate the addition of an extra lane and a narrow median.

Existing 2-lane highways should not be retrofitted within the existing footprint as that will require compromising too many cross-section parameters. The 2+1 roadway requires widening of existing 2-lane highways to accommodate standard highway elements, including shoulder, shoulder rounding, lane and median.

Design domains for the median width of 2+1 roadways range from a minimum width of 2.3 m to a desirable width up to 4.7 m, as described on table 1 below. Design domains, including minimum and desirable values, are defined for each median barrier type considered for 2+1 roadways.

Refer to Section 19 for the recommended list of barrier systems to be used on 2+1 roadways.

Minimum width: Minimum width takes into consideration barrier deflection and maintenance operations.

Median barriers should be offset at least 1 m from the travel lanes to reduce damage from snowplows and for snow storage.

The dynamic deflection is measured for all barrier systems that meet AASHTO MASH crash test requirements. For TL-3 barrier systems, the dynamic deflection is measured based on the crash test that involves hitting the barrier with a pickup truck at 100 km/h and an impact angle of 25º. The selected speed and impact angle represent the 85th percentile of real-world impact conditions of run-off-the road passenger vehicle crashes on high-speed roadways. Higher crash test levels use larger vehicles and a different combination of speed and impact angle.

Real-world deflections of median barriers on 2+1 roadways will likely be less than the recorded dynamic deflection values that define the use and limitations of MASH TL-3 barrier systems.

Minimum median width considers the reduced risk of developing the full dynamic deflection on real-world crashes and the Australian experience with 2+1 roadways. The following assumptions are made:

(1) Vehicle travels centered on its lane;
(2) Vehicle width is 2.6 m (transport truck);
(3) Lane width is 3.5 m.

$$\frac{1}{2} x\ (3.5\ m - 2.6\ m) = 0.5\ m \quad \text{(rounded up to one decimal point)}$$

Based on the above assumptions, it is acceptable to reduce the 2+1 roadway median width by allowing part of the deflection (0.5 m) to encroach into the opposite lane.

The minimum median width is the greater of (1) two times the barrier deflection minus 0.5 m minus one half of the barrier width, and (2) 2 m plus the width of the barrier. For the double sided SBGR (Blockless) median barrier system (0.3 m barrier width), the minimum median width is the larger of:

$$2\ x\ \left(1.65\ m - 0.5\ m - \frac{1}{2} x\ 0.3\ m\right) = 2\ m \ \text{ and}$$

$$2\ x\ 1\ m + 0.3\ m = 2.3\ m$$

<u>Desirable width</u>: for each barrier type being considered, desirable width takes into consideration the width needed to accommodate a disabled vehicle, the and the width needed for shy lines.

To accommodate a disabled vehicle (the TAC-GDG recommends vehicle design widths of 2.0 m for small vehicles and 2.6 m for trucks), the left (median) shoulder width should be 2.0 m minimum.

Shy lines are defined in the RDM as a function of the design speed. Shy lines for 110 km/h are 2.8 m and for 100 km/h are 2.4 m. Offsetting the median barrier to accommodate shy lines would increase the angle of impact in case of a crash and is therefore not recommended.

The desirable median width is 4.0 m plus the width of the barrier system.

The design domain for narrow medians on 2+1 roadways is as follows:

Table 1: Design Domain for Median Width

Barrier Type	Minimum Width (m)	Desirable Width (m)	Range (m)
High Tension Cable Guide Rail (HTCGR)	3.4 (2 x (2.2 – 0.5) + 0.0)	4.0 ((2 x 2.0) + 0.0)	3.4 – 4.0
Double Sided Blockless Steel Beam Guide Rail (Blockless SBGR)	2.3 (2 x 1.0 + 0.3)	4.3 ((2 x 2.0) + 0.3)	2.3 – 4.3
TL-4 Steel Beam Guide Rail	2.4 (2 x 1.0 + 0.4)	4.4 (2 x 2.0 + 0.4)	2.4 – 4.4
Guardian 5 (TL-5 system)	2.7 (2 x 1.0 + 0.7)	4.7 (2 x 2.0 + 0.7)	2.7 – 4.7

15. R.O.W. Width - nominal (m)

As there are no standards for the width of the Right of Way (R.O.W.), the existing width may be retained for the 2+1 roadway pilot project, except for locations where improvements may require a wider footprint than the existing. Fills and intersections should be assessed to determine property requirements for the 2+1 roadway improvements.

16. Posted Speed - prevailing (km/h)

Posted speed (prevailing) should be 20 km/h lower than the design speed.

17. Superelevation Maximum Rate for Determining the Radius

6% should be used as the superelevation rate for determining the radius.

18. Other Auxiliary Lanes

Turning lanes may be required for the 2+1 roadway. Auxiliary lanes should be designed in accordance with existing policies and as recommended by the TAC-GDG as modified by the MTO Design Supplement.

19. Median Barrier Types and Roadside Safety

The following barrier types are considered for the 2+1 roadway:

1. Double Sided Steel-Beam Guide Rail (Blockless)
2. High Tension Cable Guide Rail (HTCGR)
3. SBGR TL-4
4. Guardian 5

New roadside safety hardware installations should meet the applicable AASHTO Manual for Assessing Safety Hardware (MASH) crash test level acceptance criteria. Existing systems may meet MASH or the previous National Cooperative Highway Research Program (NCHRP) Report 350 criteria.

Test Level 3 is the appropriate crash test level for 2+1 roadways and is therefore recommended. Higher crash test levels may be considered in consultation with the Highway Design Office if commercial (truck) traffic is higher than 25%.

Stopping sight distances and sight lines should be considered in design. Barrier system posts may affect sight lines around curves. Figure 1 shows the effect of high tension cable guide rail with respect to sight lines on Highway 401 west of London. The Highway Design Office should be consulted if there are concerns with respect to sight lines as simply increasing the shoulder width may introduce other issues.

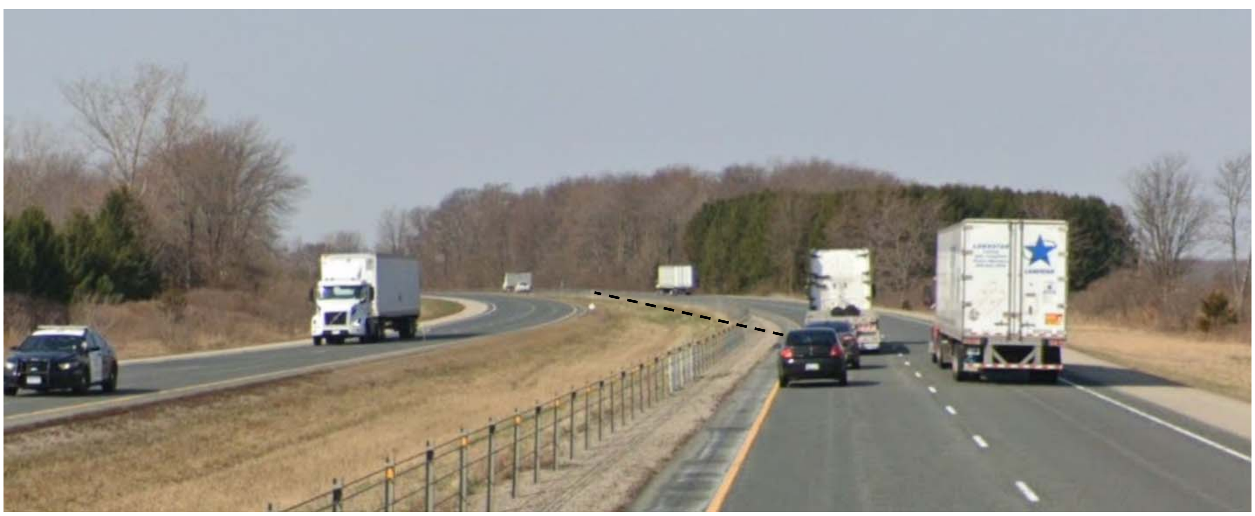


Figure 1: Effect of median barrier on sight lines around curves

Posts for existing Blockless SBGR, as well as for TL-4 SBGR and Guardian 5, cannot be driven into asphalt and would require leave-outs or a mow strip to allow the posts to rotate.

Terminal systems for Blockless SBGR systems require the use of double sided blocked Steel Beam Energy Attenuating (SBEAT) systems or narrow crash cushions. Due to length and narrower width, the use of crash cushions is recommended.

SBGR TL-4 systems use Thrie Beams instead of W-Beams used on TL-3 systems. Transitioning to a TL-3 system is needed at both ends as terminals and crash cushions are TL-3 systems. SBGR TL-4 barrier systems may be considered, in consultation with the Highway Design Office, for commercial traffic volumes higher than 25%.

The Guardian 5 barrier system meets AASHTO MASH crash test level 5 (TL-5), has a width of approximately 0.7 m and a dynamic deflection of 1.7 m. Sightlines around curves are a concern that need to be considered during design to ensure sightlines requirements are addressed. The cost of installation makes this system less desirable than other semi-rigid barrier systems. Guardian 5 may be considered, in consultation with the Highway Design Office, for special applications where the percentage of transport trucks is high. The Guardian 5 needs to transition to a TL-3 system at both ends prior to the required terminal or crash cushion.

Grading and widening will be required for the 2+1 roadway improvements. It is desirable that slopes meet the requirements in the Roadside Design Manual. Placement of roadside barriers may be considered if cost beneficial.

Rumble strips should be considered to warn motorists that vehicles are leaving the roadway, especially on the median shoulder.

20. Environmental Assessment

The standard environmental assessment process should be followed for 2+1 roadway projects.

21. Pavement

Different alternatives should be considered for the pavement structure, in consideration of the grading work that is required to widen the existing roadway for the 2+1 roadway improvements.

22. Drainage

One of the premises for the 2+1 roadway is that it is based on a flush median. The median barrier system to be used should not require special drainage works.

A drainage study may be required due to the grading work and increased impervious surface required to accommodate the improvements for a 2+1 roadway. All drainage infrastructure is to be designed and sized according to the current MTO drainage design standards.

23. Intersections

Intersections should meet the requirements of an undivided King's highway as described in the TAC-GDG and the MTO Design Supplement.

Sightlines should be assessed related to median barriers and crash cushions that will be placed around intersections.

24. Entrances

Access should be assessed during the preliminary design phase of the project to address the effect of median barriers to existing entrances. Placing breaks in the median barrier to accommodate private entrances should be avoided where possible.

25. Active Transportation Infrastructure

The design of 2+1 roadway improvements should describe how continuity will be maintained during and after construction if active transportation infrastructure is impacted by the work and/or staging.