Ministry of Transportation Ontario

2+1 Roadway Pilot Project - Site Selection Criteria

2+1 Advancement Working Group

DRAFT REPORT

Ontario

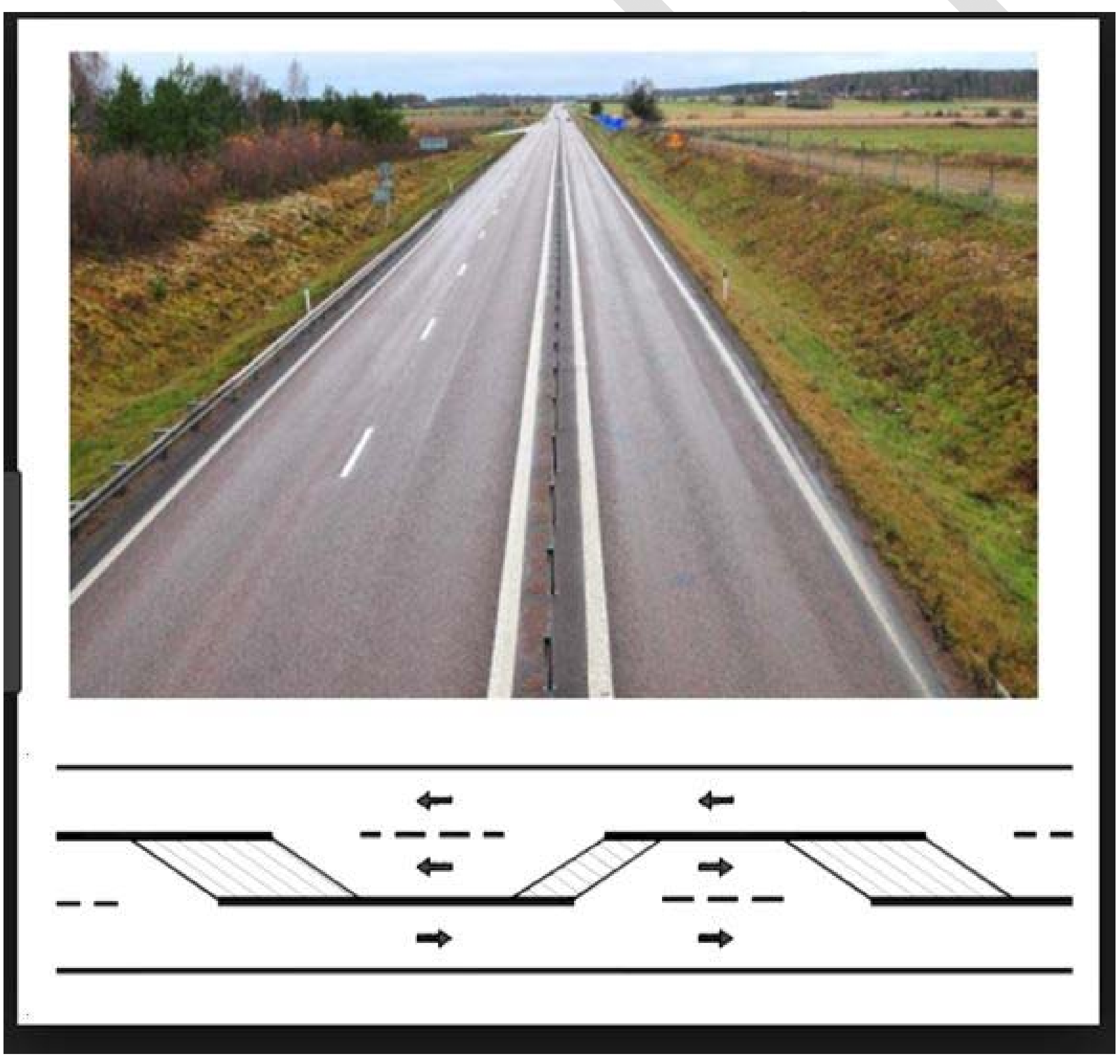
Contents

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 shown to enhance capacity and reduce some types of collisions because it allows for faster moving vehicles to pass slower vehicles at regular frequency.

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. This concept, when used in other jurisdictions, has been found to improve operational efficiency and reduce collisions for selected two-lane highways. A flush narrow median and median barrier, which helps protect against cross-over collisions, are also common features of the 2+1 roadway concept.



The findings of the 2+1 Advancement Working Group will be presented in two parts, with this first report designed to summarize site selection parameters criteria, which will guide selection of potential 2+1 roadway model pilot sites and provide designers with guidance to incorporate the 2+1 roadway model as a design tool.

A second report, will present detailed recommendations for potential sites that consider design parameters, including cross-section elements, barrier types, and other design guidance.

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 Timiskaming 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 working group is comprised of individuals from multiple disciplinary backgrounds (members are listed in Section 1.2 of this report) to provide for a well-rounded analysis of the model.

The 2+1 Advancement Working Group followed a variation of the Value Analysis (VA) process, conducted over 3 workshops held on March 4th, 11th, and 24th, 2021 to determine appropriate design parameters using existing MTO design guidance as a starting point and to determine pilot location parameters / site selection criteria that would be used to select potential 2+1 roadway pilot locations.

1.1 2+1 Advancement Working Group Members

The VA Team members are listed below:

2+1 Advancement Working Group Members	
Ryan Herbrand, (Project Lead)	MTO – Engineering Intern, Project Delivery Office, Northeastern Region - North Bay
Robert Long (Project Lead)	MTO –Supervisor, Traffic Section, Northeastern Region - North Bay
Vicente Benitez	MTO – Design & Contract Standards Engineer, Highway Design Office – St Catharines

James Hamilton	MTO – Maintenance Contracts Officer, Highway Operations Management, Northeastern Region - North Bay
Brad Thom	MTO – Manager, Highway Operations, Northeastern Region - North Bay
Justin White	MTO – Traffic Operations Engineer, Traffic Office – St Catharines
Mark Wilson	GEMS Committee – Resource Member – New Liskeard
MTO Senior Management Advisors	
John Fraser	MTO – Manager, Engineering Program Delivery, Northeastern Region - North Bay
Mike Pearsall	MTO – Manager, Highway Design Office – St Catharines

1.2 Project Initiation

During its first meeting on December 18th, 2020, the 2+1 Advancement Working Group team members were introduced, and the overall scope of the project was discussed. The process utilized a number of different tools over several meetings and workshops to help understand the scope of the project and provide recommendations for a model for use in Ontario as well as site selection criteria.

During the initial meetings, background information and previous work completed on 2+1 roadway models was reviewed. These included summary documents regarding the OPR and 2+1 Feasibility Study for the section of Highway 11 between North Bay and New Liskeard. The intent of the review was to identify any issues that might impact the feasibility of utilizing the 2+1 roadway model to support the determination of site selection parameters / criteria that would avoid or mitigate these issues. Mark Wilson of the GEMS Committee (Going the Extra Mile for Safety) presented his extensive research into 2+1 roadway models from international jurisdictions. This helped the group to better understand the components of a successful 2+1 roadway model.

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.

1.3 Project Procedure

The workshop phase began with information gathering meetings where discussion focused on various jurisdictional experiences with 2+1 roadway models, previous work conducted by MTO on 2+1 roadway models, MTO Design Guidance, standards and parameters, operational and maintenance considerations, and an initial review of design parameters. A March 4th workshop was based on a Value Analysis format, where existing MTO standards were reviewed to develop proposed parameters for a 2+1 roadway pilot location, and to prioritize these standards.

At a second workshop on March 11th, 2021, the team followed a variation of a Value Analysis process to investigate different site selection criteria and parameters. Once again, these criteria were prioritized. The criteria that will be used in the selection of a potential 2+1 roadway model pilot location was explored further during a follow up workshop.

The team also met with international authority representatives who have been involved in the implementation of 2+1 roadway models in their respective countries. The contacts included:

- Göran Fredriksson, General Manager, Swedish Road Barrier Association
- Fiona Bohane, Regional Road Safety Engineer, Transport Infrastructure Ireland,
- Alastair De Beer, Head of Road Safety, Transport Infrastructure Ireland
- Keith Barry, Associate Director, Atkins Engineering, Ireland
- Oskar Lundblad, Specialist, Road Design, Technology and Environment, Land Negotiation, Trafikverket, Sweden
- Paul Mihailidis, Director, Trafficworks, Melbourne Australia
- Daniel Mustata, Principal Road Safety Engineer, Road Solutions, Melbourne Australia

The meetings were very beneficial. They offered a first-hand experience of how different international road authorities implemented these 2+1 roadway models, some of the criteria they look for in candidate sites, as well as some of the issues they have experienced, and how these have been mitigated.

Following the meetings, the group continued to develop the site selection criteria. These criteria will be used by the various provincial offices to identify and prioritize potential locations that fit within the criteria.

Once the Design and Engineering offices identify potential candidate sites, the working group will review them and develop a prioritized ranking of locations across the province for consideration and selection of the 2+1 roadway pilot location. These potential locations will be shared for public review and comment later this fall.

1.4 Development of Site Selection Criteria

The site selection parameters / criteria developed will aid in the identification of pilot project locations. The list below summarizes the parameters developed. Section 5 of this report provides an explanation of these parameters and their associated criteria, and how they relate to the feasibility of a pilot project location. In addition, Section 6 discusses the prioritized ranking of each of these site selection parameters / criteria.

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

2.0 Design Standards

As the 2+1 roadway concept is new to Ontario, highway design standards that reflect the existing functional highway classification may not fit exactly. Existing geometric design standards will be used wherever possible. The design exception process will be used where it is not possible or economically feasible to meet the standards.

Some standards related to 2+1 roadways require the use of design domains. Where appropriate, design domains will provide flexibility for the selection of the appropriate standard.

Appendix A includes a cross section comparison for a highway section with high AADT and high % commercial, a highway section with low AADT and low % commercial, and the Swedish approach to 2+1 roadways.

3.0 Site Selection

The site selection parameters / criteria developed within this report are to be used to aid in the identification of potential pilot project locations.

The parameters and associated criteria and how they relate to the feasibility of a pilot location are identified under the site selection criteria outlined within this report.

The next phase of work will entail taking the highest-ranking potential sites derived from the site selection criteria and reviewing those sites against the applicable geometric design standards for the given roadway section. A preliminary cost estimate will then be developed, and a benefit cost analysis undertaken to aid in determining a final recommended location for the pilot.

4.0 2+1 Roadway Development and Evolution – Sweden's Experience and the Ontario Provincial Highway Context

4.1 Introduction

In 1997, the Swedish Parliament established a road safety initiative called Vision Zero. The goal was to achieve zero road deaths on the Swedish road network through the implementation of a safe systems approach to road design. The objective of zero deaths or severe injuries can be achieved, in part, by designing road networks that manage kinetic energy. One of the key components of Vision Zero is to transfer more of the responsibility for road safety to road designers and less on individual road users. The road system design should account for human error and the design of the system must reduce the energy and severity of crashes so that humans will survive. Sweden has done very well with the Vision Zero initiative and has for many years been amongst the safest countries in the world in which to drive. They topped the list in the EU (and the world) again in 2020 with a rate of 18 fatalities per 1,000,000 population.

4.2 Implementation of 2+1 Roadways

Although 2+1 roadways have been considered in various forms as far back as the 1940’s and 1950’s, they were not implemented in any significant way until Sweden adopted Vision Zero. Sweden aggressively applied safe systems design to their road network and 2+1 roadways were one of the most significant designs that were applied. They focused first on the high rates of deaths and serious injuries which were occurring across their rural highway network. These very high fatality rates, due in large part to crossover collisions, were occurring on two-lane roads with wide shoulders and posted speeds of 90 or 100 km/h.

Ontario’s fatality rate, measured over all roadways, has ranked it among the top 5 safest jurisdictions in North America for over 20 years consecutively.

Over the past 5 years there have been, on average, 138 fatal collisions resulting in an average of 157 fatalities per year on the provincial highway network. This equates to approximately 11 fatalities per 1,000,000 population. Of the 5-year average of 138 annual fatal collisions across the province, 41 (30%) were “crossover" or “approach” type collisions. While these numbers represent the experience on the provincial highway network only, as compared with all road networks in Sweden, it is indicative that the provincial highway network in Ontario does not correlate with the very high fatality rates identified by Sweden in 1997.

In Sweden, road designers considered how they could prevent crossover collisions while also keeping costs down. They eventually decided to test the 2+1 roadway model on their 13 m wide roads. They took the 13 m cross-section, which consisted of two lanes (one for each direction of travel) with two wide shoulders and converted it into a road system that consisted of a three-lane cross-section with continuously alternating passing lanes and a central flush median which contained a physical barrier of either a high-tension cable barrier (HTCB) or semi-rigid steel barrier. The resulting cross-section consisted of narrow outside shoulders (1 m or less), lanes of 3.25 m for the two-lane direction and 3.5 m for the one-lane direction, and a 1.5 m median. After a successful pilot project, Sweden continued to build 2+1 roadways with median barriers and have continued to expand their network by adding new 2+1 roadway projects every year. They now have over 3,000 km of 2+1 roadway sections. 2+1 roadway sections in Sweden are built on two-lane two-way roads with Average Annual Daily Traffic (AADT) volumes that range from 2,000 AADT to about 18,000 AADT.

In Sweden, the most significant result of the 2+1 roadways was the virtual elimination of deadly head on collisions. Fatality rates fell drastically on these converted rural roads with studies showing reductions of between 55 and 80%, and a country-wide reduction in overall road fatalities of 50%. Other countries looked at the success that Sweden had experienced and began pilot projects of their own. For example, Ireland built four pilots and saw fatality rates drop significantly. Australia has also adopted the 2+1 roadway model in a significant way, and they have built a large 2+1 roadway network in a relatively short time and have also seen positive results. Both Sweden and Ireland have compared safety performance of 2+1 roadways with divided highways and have found that they perform equally. They have recognized that for a significantly lower investment they are achieving equal safety results.

It should be noted that in addition to introducing the 2+1 roadway system, Sweden implemented other safety measures such as the reduction of truck speeds and extensive application of photo radar with an associated increased fine structure. The contribution of these two measures to the reduction in fatal collisions experienced should not be ignored. It should also be noted that although fatalities are known to decrease with the implementation of the 2+1 roadway concept, there is also a recognized increase in property damage collisions arising from the use of median barriers.

Ontario has also been working on reducing crossover collisions and has introduced centreline rumble strips on provincial highways. Centreline rumble strips alert drivers that they are about to cross the centreline and are shown to reduce fatal and injury collisions by up to 64%. Rumble strips are an extremely low-cost method of reducing collisions as compared with any other model.

Other research that Ontario is following includes a recent study that is nearing completion by the Texas Transportation Institute (TTI). The study, (report NCHRP 17-66), correlated narrow medians (buffer areas) and collision reduction. The study shows that as a median is increased, there is a corresponding decrease in opposite direction crashes. With a 1.2 m buffer, there is a 35% collision reduction. This increases to an 85% reduction for a 2.5 m buffer and 90% for a 3 m median. This study does not include the provision of a median barrier.

In Sweden, the first 2+1 roadway sections were built on existing two-lane roadway cross-sections that transformed the two-lane roadway to a 2+1 roadway. The shoulder width was reduced to allow for a 3rd lane and a median containing a physical barrier. These initial 2+1 roadway sections were constructed on rural environments with at grade entrances and intersections. For existing residential or commercial entrances, two treatments were typically used, depending on various factors including traffic volume and sight distances. The first treatment consisted of a small gap in the barrier. This would allow access from both directions of travel with little disruption. The second treatment required closing access from/to the non-adjacent direction of travel. The second treatment required closing access across the median and limiting access to right-in right-out. This treatment would be chosen where an existing entrance (prior to 2+1 roadway) may not have been placed in a safe location. If the entrance was close to an intersection, an extension of the driveway or a short service road was built to the intersection or, alternatively, the driver entered the highway with a right-hand turn and travelled a short distance to an intersection. At this intersection there was a turn-around area provided so the driver can travel in the opposite direction. These designs reduced disruption for landowners.

Three types of intersection treatments were developed for use on 2+1 roadways. The first is a traditional 4-leg intersection with left turns lanes for vehicles wishing to turn left. The second type is a “jug handle” type treatment that directs drivers to exit right from the road where they access a type of at-grade ramp that brings them perpendicular to the highway. Here they stop to look for approaching traffic from both directions and proceed when safe. This treatment is often installed in conjunction with sideroads and pull-off areas and is also used on long sections of 2+1 roadways where there are few entrances or intersections but regular turn around opportunities are still required. The last treatment is the use of a roundabout, which is effective at slowing traffic while maintaining flow and significantly improving the safety of the intersection.

While Sweden has seen positive results with the introduction of a median barrier, it should also be noted that these barriers could be associated with an increase in wrong way travel, a condition that previously would not have existed without barriers on these roadways.

4.3 Barrier Changes

Over the last 25 years, there have been many developments in barrier design. As previously indicated, the first 2+1 roadways in Sweden were built using a High-Tension Cable Barrier (HTCB) median barrier. Many kilometres of HTCB was installed in the median reserve and there were reductions in road fatalities. Other countries around the world also installed HTCB systems in narrow medians on 2+1 roadways. Looking for lower maintenance barrier options, however, various road authorities also began to consider semi-rigid steel barriers. These steel barriers performed well and were less costly to maintain than HTCB.

Both Sweden and Ireland have indicated that new 2+1 and 2+2 roadway installations will use semi-rigid steel barriers. It should be noted that the dynamic deflection of all these products is tested to EN1317 standards in Europe and MASH standards in North America and Australia. Because these barriers are normally placed in a 1.5 m flush median, there was some initial concern that there would be situations where vehicles that come in contact with the barrier may enter into the oncoming lane due to deflection of the barrier. Crash tests are conducted at angles that are greater than typical angles of impact experienced on 2+1 roadways. Road authorities in Sweden that install barriers in narrow medians have found that it is rare for a vehicle to enter the opposing lane and when it does, the barrier deflects and both the vehicle and barrier bounce back in a relatively short period of time, absorbing energy and reducing the possibility of head-on collisions.

Guide rail systems used on Ontario provincial highways are tested to meet the Manual for Assessing Safety Hardware (MASH) crash test requirements. MASH represents the latest and current standard in North America. The High-Tension Cable Barrier (HTCB) that was originally used by Sweden did not meet MASH standards and is not supported by MTO. When the operational performance review of Highway 11 took place in 2018, there were no median barriers for a two-lane, two-way roadways that were acceptable to MTO, thus causing concern about implementing the Swedish model at that time. Since then, narrow median barrier systems that meet MASH standards have been approved by MTO for use on Ontario highways.

4.4 Evolution of 2+1 Roadway Model Design

In addition to changes in the design of barriers there have also been some changes in cross-sections in some countries. As mentioned at the beginning of Section 2, Sweden’s first 2+1 roadways were built on existing 13 m roads. The resulting shoulder on both sides of these roads were narrow. New projects in Sweden, especially projects on new alignment, require wider shoulders to allow more room. Sweden is also building 2+1 roadways on their 9 m roads by installing median barrier and widening the road in some areas to allow for passing opportunities. These roads have long sections of 1+1 cross-section with passing lanes (2+1) on widened sections.

Other countries have also made some design changes, including Ireland and Australia. Ireland has used a slightly wider cross-section for some 2+1 roadways, and they have built many 2+2 roadway sections (four-lane roads with two travel lanes in each direction) which also have a barrier in a narrow median. These were built to address volume issues that could not be accommodated by 2+1 roadways. Australia also uses a wider 3 m shoulder in their design and in addition to the widespread use of median barriers, there is extensive use of continuous roadside barriers to address road departure issues. Another evolution is the reduction in the number of at grade intersections where higher volumes increase the risk of crashes at these intersections.

These higher volume locations require the installation of either overpasses or underpasses to reduce or eliminate traffic conflicts.

Cross-section elements and roadside design are of utmost importance to MTO in ensuring a safe roadway for all users. Sweden was willing to reduce some of these design elements in favour of tackling a larger problem with crossover collisions. Ontario does not experience the same level of crossover collisions as Sweden and is cautious in its approach to reducing any of the roadside safety elements. While it is anticipated that lane widths, generally between 3.5m to 3.75m (see Appendix A) will not be reduced, MTO is developing design domains for cross-section elements related to the 2+1 roadway pilot project, including but not limited to median width and barrier encroachment, to reduce costs associated with widening of the existing roadway footprint. Design domains will be presented in the second report to be produced by the working group later this fall.

4.5 Maintenance of 2+1 Roadways

In Sweden, the switch from HTCB to semi-rigid barriers has changed the maintenance requirements for 2+1 roadways. While HTCB requires repair after any contact, semi-rigid barriers can withstand some impact and continue to function effectively. Snow removal requires more passes or tandem plowing, compared to two-lane sections. Snow does not accumulate in the median because plows travel relatively close to the median barrier.

On Ontario highways, increasing the roadway platform with the addition of a third lane and centreline barrier will result in increased winter maintenance costs due to the requirements for additional equipment and labour in addition to the maintenance costs associated with the placement and maintenance of a median barrier.

In Sweden, the set-up for maintenance activities on 2+1 roadways are usually carried out on the two-lane portion of the highway allowing traffic to move past on each side of the work crew. Work crews are protected with the use of traffic control devices to perform their work safely on 2+1 roadways. Counterflow can also be set up by using turn around locations or by temporarily removing the median barrier where HTCB is used. It is not feasible to temporarily remove semi-rigid barrier. A wider cross-section is beneficial and allows to have more room for service vehicles to perform maintenance activities on the single lane side.

Maintenance or breakdowns on the single lane side of the 2+1 roadways in Sweden requires extra measures compared to conventional two-lane roads. This includes trained personnel temporarily removing barrier to allow traffic to resume flow. There are increased delays when dealing with these scenarios as traffic is often stopped until flow can be reinstated. The potential delays associated with breakdowns or minor collisions is of concern to MTO.

4.6 Emergency Response on 2+1 Roadways

One of the advantages of 2+1 roadways is the reduction in serious incidents that result in fatalities and serious injuries. The outcome is fewer incidents that require major deployments of emergency services as well as a significant reduction in long fatality investigations. Experience from jurisdictions with 2+1 roadways show that there will be contact made with the median barrier and some of these contacts will lead to the need for towing services. Contacts of this types also indicate that possible fatal collisions may have been averted. Generally, disturbances on these 2+1 roadways are not excessive and in Sweden 2+1 roadways have fewer disturbances than on motorways according to a disturbance index that is used to evaluate delays on the road network.

As noted previously, although fatalities are known to decrease, there is also a recognized increase in property damage collisions arising from the use of centreline barrier. When these collisions occur on the single lane portion of the highway, delays can occur if the damaged vehicle has been disabled and there is no way around the disabled vehicle. This can also happen with vehicle breakdowns or with wildlife collisions where either the vehicle or carcass of an animal may impede traffic flow. These events may restrict or potentially limit pass-by traffic until the obstacle is removed and may therefore impede emergency response to the incident. On one-lane sections, access to such vehicles may pose a challenge where queues have formed creating the need for alternate access to a disabled vehicle. As queues form, these events may occur with wildlife collisions where the vehicle and or carcass remains within the travel lane. There is also a heightened potential of additional collisions to the initial event, particularly on rural highways where restricted sight lines conditions related to lack of daylight and or inclement weather are more frequent.

4.7 Operating Speeds and Traffic Performance

One of the aspects of 2+1 roadways that warranted analysis was the possible negative effect the road model would have on traffic operations. Studies of 2+1 roadways in Sweden indicated that Level of Service was better than expected and operating speeds increased slightly due to more passing opportunities as well as an increase in speed limits.

4.8 Public Perception

Sweden faced some early resistance to 2+1 roadways. There was, for example, an outcry before the opening of the first pilot with claims that it would be a disaster. The thinking shifted following the opening because the 2+1 roadways were saving lives. This brought many people and groups onside and in Sweden there is now wide support for the 2+1 roadway design. The success in Sweden meant other countries faced less resistance and now 2+1 roadways are built around the world.

4.9 Conclusions Drawn from Swedish Experience

In Sweden, 2+1 roadways with median barriers are an example of a Safe System Road design. Developed in Sweden in the 1990's they have become a standard fixture, not only in Sweden but many other countries around the world. They have been implemented as a response to growing traffic volumes and high fatality rates that were associated with rural roads in Sweden (Ontario isn't seeing these high fatal rates on rural highways).

2+1 roadways have evolved over time as more jurisdictions have modified the design to fit their road networks. 2+1 roadways have had positive safety results as well as positive effects on traffic flow.

A pilot of the 2+1 roadway in Ontario would require addressing property and environmental impacts, maintenance requirements, and required widening. Identifying the pilot location will require balancing traffic volumes, collision types, maintenance requirements, geography, and existing cross-section elements.

5.0 Site Selection Criteria

Section 5 discusses site selection parameters and the individual criteria developed by the 2+1 Advancement Working Group. It provides details regarding the rationale for each criterion, how they are measured, and how they are to be scored.

The score for each parameter / criterion is then applied against a weighted prioritization and combined with the weighted scores of the other parameters / criteria to determine the overall feasibility of a given site.

5.1 Traffic Operating Characteristics

A 2+1 roadway model, if utilized properly, can provide operational benefits from a capacity perspective as well as from a safety perspective. The criteria outlined in Section 3.1 are designed to ensure that the potential for operational benefits from a capacity perspective are accounted for in selecting an appropriate site.

5.1.1 Volume

Traffic volumes in relation to the overall capacity of a highway directly affect the operation of the highway. The capacity of a highway is a quantitative measure influenced by the number of lanes available, their width, the road alignment, the terrain, speed, geometry, percentage of commercial vehicles, number of intersections and even weather. The Level of Service (LOS) is a qualitative measure of a facility. LOS A represents a free-flowing facility with little to no interruptions to driver maneuverability ranging to LOS F which represents a traffic jam with no driver maneuverability.

On two-lane two-way highways, the volume does not have to reach capacity for the operation to be affected. When any number or combination of the influences noted above occur, queuing and/or delays that develop can contribute to aggressive driving where unnecessary risks are taken. The combination of limited passing availability, slow moving vehicles and steep vertical alignments often result in the formation of traffic queues and delays to traffic.

Where limited passing opportunities, slow moving vehicles, road alignment and long or steep vertical curves are present on a two-lane highway, there is a range of volumes wherein an improvement to the level of service can be expected if passing opportunities are introduced. The range in AADT that could be expected to benefit the most from the application of a 2+1 roadway (passing lanes) is 4000 to 15000. Under 4000 AADT, the addition of a passing lane would be expected to provide limited improvement in operation. As volume increases beyond 4000 AADT an improvement in the level of service can be observed up to an AADT of 18000. Over 18000 AADT, even with the addition of a passing lane, no noticeable improvement to the LOS would be expected. The greatest range of volumes where an appreciable benefit can be gained by the addition of a passing lane is from 4000-9000 AADT. The higher range AADT of 9000-18000 would be consistent with locations where 4-laning may start to be a consideration and serve as a holding strategy to improve operation until future expansion can be planned.

For the purposes of selecting highway sections that could benefit from the installation of a 2+1 roadway system, the range of AADT to be considered should be from 1000 to 15000.

Volume Criterion Measurement

The following scores are recommended for use in determining the volume criteria:

- 1000 to 4,000, or > 15,000 receives a score of one (1)
- 9,001 to 15,000 receives a score of two (2)
- 4,001 to 9,000 receives a score of three (3)

5.1.2 Speed

The posted speed relates directly to the design and operating characteristic of the highway. Generally, as the speed increases, the potential for an increase in the severity of collision can be expected. The range of speeds where the 2+1 roadway system can serve to improve the safety of a facility by reducing high severity collision types would be expected on higher speed facilities with speeds from 70 to 90 km/h.

Speed Criterion Measurement

The following scores are recommended for use in determining the posted speed criteria:

- 70 km/h receives a score of one (1)

- 80 km/h receives a score of two (2)
- 90 km/h receives a score of three (3)

5.1.3 Passing Lane / Truck Climbing Lane Warrant

As outlined within the TAC Geometric Design Guide for Canadian Roads, June 2017, the inability to pass on a two-lane road is a frequent cause of driver frustration. Where queues exceed an acceptable level, unsafe passing maneuvers may result. Driver frustration occurs where all or some of the following characteristics are present:

- Rolling or rugged terrain
- Unrealistically low speed
- A high proportion of long distance, high-speed trips
- A significant percentage of slow-moving vehicles causing queuing
- Traffic volumes high enough to restrict passing but too low to warrant widening

Under the collision frequency portion for passing lanes and truck climbing lanes within the TAC manual, it is reasonable to estimate the effect of a passing lane / truck climbing lane of 5% reduction in Property Damage Only (PDO) collisions, 30% reduction in injury collisions and a 60% reduction in fatal collisions.

Passing lanes can be a cost-effective enhancement to improve operations and defer the need for a four-lane facility. Studies indicate substantial benefits in traffic operations could be achieved at quite low costs.

MTO uses a method in their design process identified as assured passing opportunities, acceptable platoon length with consideration of passing lane frequency.

Passing Lane / Truck Climbing Lane Warrant Criterion Measurement

The following Yes/No is recommended for use in determining the passing lane / truck climbing lane criteria:

For a pilot project location to be considered, one of the below-mentioned criteria must be met, otherwise the option should be given no further consideration.

Max score for this criterion is one (1). Once a criterion is met the others can be skipped. If no criteria are met, then discontinue with analysis of the highway section.

- Lane holding strategy:
    - A proposed location nearing capacity that would require future 4-laning to be conducted. Considering a 2+1 roadway model provides an option which was not necessarily considered before, to address capacity, much like a holding strategy.

    - If yes, receives a score of one (1),
    - If no, receives a score of Zero (0)

- Existing passing lanes:
    - A proposed pilot location with an existing passing lane(s) that could be retrofitted into a 2+1 roadway model. These locations already show signs of requiring Level of Service (LOS) improvements by increasing passing opportunities and would benefit further by introduction of a 2+1 roadway model and could be done in a cost-effective manner due to existing infrastructure.
    - If yes, receives a score of one (1),
    - If no, receives a score of Zero (0)

- Passing lanes / truck climbing lanes are warranted at Proposed Site:
    - This follows the current process of adding a lane for the purpose of passing
    - If yes, receives a score of one (1),
    - If no, receives a score of Zero (0)

5.2 Existing Highway Safety Performance

The criteria discussed in this section are in relation to the existing highway safety performance for a given section of highway being proposed as a potential pilot location for a 2+1 roadway model. These criteria deal with collision data, historical trends, and previously reviewed safety measures for a given highway section to ensure that the proposed pilot location would be able to address and improve upon the existing highway safety performance.

5.2.1 Consideration of Safety Improvements Implemented

Determining where a 2+1 roadway could be implemented should include a review of what intermediate steps have been taken to date to address operational concerns that were identified. For example, where crossover centreline collisions are present, have other proven and cost-effective measures such as centreline rumble strips been considered to address these concerns? Where other alternatives have not been considered, it may be beneficial to review the potential for these options prior to moving forward with an extensive 2+1 roadway system to address these operational issues.

<u>Intermediate Steps Taken Parameter Measurement</u>

The following scores are recommended for use in determining if alternative measures have been considered and or trialed:

- If previous alternative safety improvements have not been investigated and/or trialed, the score will be one (1)
  If previous alternative safety improvements have been investigated and/or trialed, the score will be two (2)
  If previous alternative safety improvements have been implemented and the benefit has been determined to be insufficient, the score will be three (3).

5.2.2 Total Number of Expected Equivalent Property Damage Only (EPDO) Collisions

The observed collision frequency will fluctuate from year to year due to both natural random variation and changes in site conditions that affect the number of collisions. The assumption that the observed collision frequency over a short period represents a reliable estimate of the long-term average collision frequency fails to account for the non-linear relationship between collisions and exposure (traffic volume). In order to account for these limitations, predictive methods are used for the estimation of the expected average collision frequency. Expected average collision frequency is the frequency expected to occur over the long-term for a given roadway with no change in the site's conditions.

Both collision frequency and severity are important metrics to consider. Equivalent Property Damage Only (EPDO) analysis assigns weighting factors to collisions by severity to develop a single number that combines both the frequency and severity of collisions by site.

Every year the Provincial Traffic Office conducts network screening. Staff can easily find the expected EPDO collisions from the provincial network screening results. The sites are organized by LHRS and offset for every 1 km stretch of highway. The expected EPDO collision units are collisions/km/year and are based on the five most recent years of data.

The length of the possible locations can influence safety benefits as a longer length has greater exposure and therefore greater potential safety benefit. To account for this and compare locations, the total expected EPDO collisions will be divided by the length of the highway section.

To calculate total expected EPDO collisions for a given highway section.

Expected EPDO = Total Expected Frequency / Total Length

For example, in the 12 km Highway 11 location shown below, the expected EPDO would be the following:

Expected EPDO = 38.72 / 12 = 3.23 EPDO collisions/year/km

Figure 1: Expected EPDO Example Table

LHRS	Start Offset	End Offset	Hwy	Subtype	Region	EXPECTED Frequency
17275	0	1	11	MTO_NER_Seg/Rur; 2-lane	NER	4.16
17275	1	2	11	MTO_NER_Seg/Rur; 2-lane	NER	3.43
17275	2	3	11	MTO_NER_Seg/Rur; 2-lane	NER	2.77
17275	3	4	11	MTO_NER_Seg/Rur; 2-lane	NER	2.61
17275	4	5	11	MTO_NER_Seg/Rur; 2-lane	NER	2.85
17275	5	6	11	MTO_NER_Seg/Rur; 2-lane	NER	4.22
17275	6	7	11	MTO_NER_Seg/Rur; 2-lane	NER	5.63
17275	7	8	11	MTO_NER_Seg/Rur; 2-lane	NER	3.52
17275	8	9	11	MTO_NER_Seg/Rur; 2-lane	NER	2.94
17275	9	10	11	MTO_NER_Seg/Rur; 2-lane	NER	2.02
17275	10	11	11	MTO_NER_Seg/Rur; 2-lane	NER	2.36
17275	11	12	11	MTO_NER_Seg/Rur; 2-lane	NER	2.21
			Total			38.72

Total Number of Expected Equivalent Property Damage Only (EPDO) Collisions Criterion Measurement

This metric is intended to emphasize those locations with the greater opportunity for collision reduction.

The following scores are recommended for use in determining the potential for reduction in EPDO collisions:

- An EDPO between 0-4.99 receives a score of one (1)
- An EDPO between 5-9.99 receives a score of two (2)
- An EDPO of 10 or higher receives a score of three (3)

Please note that when determining highway section lengths for consideration as a 2+1 roadway, it may be advantageous to adjust the limits of the section to gain the greatest benefit from a collision reduction perspective.

5.2.3 Collision Impact Type

Collision impact type is an important data point as 2+1 roadways are, in general, aimed at reducing approaching and sideswipe collisions. However, there are no predictive methods for collision impact type, only frequency and severity. Collision impact type is indirectly addressed in EPDO collisions as approaching and sideswipe collisions are generally severe in nature which is accounted for in EPDO collisions. However, to provide greater emphasis on approaching and sideswipe collisions, an over representation collision type analysis will be conducted to determine if these collision types are overrepresented compared to what is expected for a typical two-lane highway. For the purposes of this review, a review of the five most recent years of collision data and collision type will be enough to rank locations. Locations will be scored against a threshold if a combination of sideswipe and approaching collisions represent above/below 10% of all collisions.

For example:

Site A had 72 total collisions in the 5 most recent years. Of those, 7 were sideswipe collisions and 4 approaching collisions. Therefore, sideswipe and approaching collisions represent 15% of the total collisions.

Collision Impact Type Criterion Measurement

The following scores are recommended for use in determining the percentage of sideswipe and approaching collisions criteria:

- If the percentage of sideswipe and approaching collisions for a given area represents 10% or more of the total collisions, then a score of three (3) is given.
- If the percentage of sideswipe and approaching collisions for a given area represents less than 10% of the total collisions, then a score of zero (0) is given.

5.2.4 Wildlife Collisions

Within the Ontario Traffic Manual Book 6, Warning Signs, the warrant for deer / moose crossing warning signs identifies the requirement to warn motorists where the following conditions exist:

- Eight kilometres or less with at least one deer or moose collision annually for at least 5 years; or
- Highway sections less than 1.5 km with at least 4 deer / moose collisions over one-year period.

With the implementation of a 2+1 roadway system the ability to manoeuvre around large wild animals that are standing or lying within the travel portion after being struck may be severely impeded. The damage to vehicles from these animals can be significant and cause vehicles to be immobile. With a barrier system in place, there are potential safety concerns related to stranded vehicles and wild animals. Historical rates of a high number of collisions pertaining to large wild animals should be taken into consideration when selecting 2+1 roadway locations. The presence of these conditions may not necessarily rule out a potential pilot candidate but may aid in the selection process and flag the necessity for potential mitigation strategies or measures.

Wildlife Collision Criterion Measurement

The measurement of this criterion is based upon OTM Book 6 warrants for wildlife crossing warning signage. These warrants are based upon wildlife collision history and are used in areas of higher frequencies of these types of collisions.

The following scores are recommended for use in determining the wildlife collisions criteria:

- If the wildlife warning signage is currently not warranted, then a score of one (1) is given.
- If the wildlife warning signage is currently warranted, then a score of zero (0) is given.

5.3 Median Barrier Continuity

The installation of median barriers has been associated with a potential reduction of collision severity on 2+1 roadway sections. Selection of an appropriate barrier type should take into consideration different road users. The use of flexible barrier (cable guide rail systems) has raised concerns with motorcycle groups in jurisdictions that have implemented 2+1 roadway systems. The pilot location should consider existing road users as barriers are considered hazards and there are implications with their use, which include increased barrier strikes, resulting in an increased number of property damage collisions, increased maintenance and traffic management related to repairs, and emergency services response.

The criteria discussed in this section are in relation to the features of the highway section that would lead to breaks in the median barrier. Barriers function better when they are continuous. Intersections and entrances, which may require breaking barrier continuity, have the potential to reduce the overall effectiveness of the barrier system.

5.3.1 Minimize Intersections

The process for determining where a 2+1 roadway could be implemented should include reviewing existing at grade intersections within a given highway section.

The measurement of this parameter is based upon the number of at-grade intersections that would require the median barrier to be terminated for the intersection itself and reinstated after the intersection. It should be noted that it is possible that not all intersections will require barrier termination. While in these circumstances, the intersection should not be counted, for the purposes of identifying candidate locations, all intersections will be counted.

This will give MTO the opportunity to monitor how these intersections, that do not require barrier termination, operate during the pilot project and will provide valuable information.

Minimize Intersections Parameter Measurement

The proposed number of intersections requiring barrier termination, over 5 km sub-sections, will be used to determine the score for this parameter. The number of intersections requiring barrier termination per 5 km sub-sections, will be used to determine the score for this parameter. For candidate locations longer than 5 km, the average of each 5 km sub-section within the section limits will be used.

The following scores will be used to determine the intersection criteria:

- If there are 5 or more Intersections per 5 km, the location receives a score of one (1)
- If there are 3-4 Intersections per 5 km, the location receives a score of two (2)
- If there are 0-2 Intersections per 5 km, the location receives a score of three (3)

5.3.2 Minimize Entrances

Much like the previously discussed intersection criterion, the process for determining the pilot location should include reviewing the existing entrances within a given corridor. Similar to intersections, it is anticipated that not all entrances will require barrier termination, in fact, most will not. This, however, creates a new issue: the potential for wrong way travel. Both the potential for barrier drops, as well as the potential for wrong way travel, have led to the feasibility rankings discussed below.

Minimize Entrances Criterion Measurement

The measurement of this criterion is based upon the number of entrances within a proposed section of highway for a 2+1 roadway pilot project. For the purposes of determining the scores for this criterion, and due to the potentially varying section lengths, the average number of entrances per 5 km sub-sections will be used:

- If there are 5 or more entrances per 5 km, the location receives a score of one (1)
- If there are 3-4 entrances per 5km, the location receives a score of two (2)
- If there are 0-2 entrances per 5 km, the location receives a score of three (3)

The difference in relative impact of an intersection compared to an entrance is reflected in the weight given to each individual criterion.

5.4 Minimize Widening Issues

The criteria discussed in this section are related to existing features along the highway alignment that would make widening (to include a narrow median, and the third lane typical of the 2+1 roadway model) more challenging or costly. These features would either require the 2+1 roadway model to be reduced to the existing highway cross-section at these areas and resume a 2+1 roadway model afterwards or increase the cost of implementing the model substantially. The 2+1 roadway model already allows for both lanes to experience the addition and subtraction of additional lanes throughout the full length of the proposed pilot section. Adding additional lane drops due to widening issues, or removing these issues entirely, is neither cost effective nor beneficial.

5.4.1 Minimize Bridges

The widening of a bridge to incorporate a 2+1 roadway is not recommended due to the potentially high cost associated with this approach. If a proposed location does contain bridges, it is recommended that the 2+1 roadway model cross-section is not carried for the duration of the structure, as well as a short distance to either side. While this option is more feasible from a cost benefit perspective, it is not ideal for a pilot as it breaks up the 2+1 roadway cross-section making it more difficult to design, construct and evaluate. A higher frequency of bridges is, therefore not recommended.

Minimize Structures Criterion Measurement

For the purposes of determining feasibility, the entire highway section being proposed, regardless of length, is to be considered.

The following scores are recommended for use in determining the bridge criteria**:**

- If there are 3 or more bridges, the location receives a score of one (1)
- If there are 1-2 bridges, the location receives a score of two (2)
- If there are 0 bridges, the location receives a score of three (3)

5.4.2 Minimize Structural Culverts

Similar to the bridge criterion, structural culverts can have their own related issues. However, these structures often have a more cost-effective means for widening. It was therefore determined that a separate criterion was necessary for their review. The difference in complexity in modifying the roadway for bridges vs structural culverts is reflected in the weight given to each individual criterion.

If a candidate section of highway has structural culverts, consideration should be given to widening if it is cost effective. However, if widening of the structural culvert is not determined to be cost effective, it is recommended that the 2+1 roadway cross-section not be carried for the duration of the structure, and that the 2+1 roadway be removed for a short distance for each approach. However, as noted previously, the preference is that the 2+1 roadway cross-section not be removed for short distances and it is therefore recommended that the pilot location not include a high number of structural culverts.

Minimize Structural Culverts Criterion Measurement

For the purposes of determining feasibility, the entire highway section, regardless of length, is to be considered.

The following scores are recommended for use in determining the structural culvert criteria:

- If there are more than 3 structural culverts, the location receives a score of one (1)
- If there are 2 structural culverts, the location receives a score of two (2)
- If there are 0-1 structural culverts, the location receives a score of three (3)

5.4.3 Minimizing Complexity of Grading

Widening can be complex and result in high costs to achieve the desired construction outcome. Consideration of the complexity of the grading work can help identify locations that may be less cost effective due to high complex excavations at deep swamps / water bodies, complex parallel drainage, unsuitable soils, rock cuts exceeding 10 m high and high embankments (e.g. 6 m high rock fills that extend for lengths more than 200 m). Although widening may be constructible, it may not be cost effective. If the complexity of grading is foreseen to be extensive, it is recommended to remove the 2+1 roadway cross-section for the duration of the highly complex grading area(s), as well as on each approach. While this option is more feasible from a cost benefit perspective, it is not ideal for a pilot as it breaks up the 2+1 roadway cross-section, making it more difficult to design, construct and evaluate. A higher frequency of complex grading shall not rate as high. In these locations, where widening is not a viable option, the application of a 1+1 roadway may provide a mitigation measure that allows the continuous benefit of the centreline barrier linking 2+1 roadway sections together.

Minimize Complexity of Grading Parameter Measurement

This criterion is to be used based on a desktop review. No new investigations are required, existing knowledge with applied engineering judgement of the existing conditions should be used.

For the purposes of determining feasibility, the entire highway section being proposed, regardless of length, is to be considered.

The following scores will be used to determine the complexity of grading criteria:

- If deep swamp / water bodies, complex parallel drainage, unsuitable soils and rock cuts over 10 m are found throughout the limits, the location receives a score of one (1)
- If a mix of both routine grading and no extreme deep fill swamps / water bodies are found, the location receives a score of two (2)
- If routine grading cut fill balance or existing roadway platform is utilized, the location receives a score of three (3)

5.5 Minimize Variable Message Signs (VMS) & Road Weather Information Systems (RWIS) Locations

Widening of the highway platform in the vicinity VMS and RWIS locations is challenging. If a particular section of highway being proposed has one of these features, located on only one side of the road (i.e. not an overhead VMS structure with supports on both sides), an option that should be considered is widening the highway platform to incorporate a full 2+1 roadway opposite to the VMS/RWIS (if on only on side of the highway). If this option is not cost effective, or if the overhead sign support is located on both sides of the highway, it is recommended that the 2+1 roadway cross-section be eliminated for the duration of the feature.

Minimize Variable Message Signs (VMS) & Road Weather Information Systems (RWIS) Locations Parameter Measurement

For the purposes of determining feasibility, the entire highway section being proposed, regardless of length, is to be considered.

The following scores are recommended for use in determining the VMS & RWIS criteria:

- If there are 2 or more VMS/RWIS installations, the location receives a score of one (1)
- If there is 1 VMS/RWIS installation, the location receives a score of two (2)
- If there no VMS/RWIS installations, the location receives a score of three (3)

5.5.1 Reduce or Eliminate Adjacent Traffic

The criterion discussed in this section consider road users that do not operate at highway speeds. These include bicycle traffic, horse-drawn vehicles and agricultural vehicles. These types of traffic that travel on the shoulders of several highways in the province can lead to potential safety and operational impacts. This is especially true when considering the single lane traffic sections of a 2+1 roadway. As such, it is recommended that where this traffic condition exists, proper separation and or protection should be provided, otherwise these areas should be omitted from consideration.

5.5.2 Cycling Traffic

The process for determining where a 2+1 roadway system could be implemented should include a review of the provincial cycling network to determine if the proposed candidate section is situated on the network. If so, the MTO Bikeways Design Manual must be followed. Additional operating space and separation may be a requirement for cycling traffic based on the operating characteristics of the highway section, as per the Bikeways Design Manual. Any additional widening necessary to meet these requirements would need to be satisfied for consideration of a 2+1 roadway pilot adjacent to provincial cycling network.

Cycling Traffic Criterion Measurement

For the purposes of determining feasibility, the entire highway section being proposed, regardless of length, is to be considered.

The following scores are recommended for use in determining cycling traffic criteria**:**

- If the highway section is part of the provincial highway cycling network, and the area is not conducive to providing proper separation and or operating space as per the Bikeways Design Manual, the location is to be omitted from consideration.
- If the highway section is part of the provincial highway cycling network, but is conducive to providing proper separation and or operating space as per the Bikeways Design Manual, the location receives a score of two (2)
- If the highway section is not part of the provincial highway cycling network, the location receives a score of three (3)

5.5.3 Horse-Drawn Vehicles

When reviewing the potential placement of a 2+1 roadway, consideration should be given to areas of a highway where horse-drawn vehicles are known to travel.

With their slow travel speed relative to cars and trucks, their vulnerability and the potential risk of unpredictable animal behavior, the combination of a 2+1 roadway system adjacent to their operation presents a significant safety concern. The placement of the centreline barrier specifically in the direction of a single lane, poses a hazard for horse-drawn vehicle operators as well as vehicles desiring to pass with limited space available to do so. The speed differential is significant enough to create safety concerns not only for the horse-drawn vehicles but the potential for queue end collisions.

A 2+1 roadway system is incompatible with an area where horse-drawn vehicles are known to operate, unless adequate provisions could be provided to accommodate the horse-drawn vehicles separately.

Horse-Drawn Vehicle Criterion Measurement

The following pass / fail criteria are recommended for use in determining the horse drawn vehicle parameter measurement.

For a pilot project location to be considered, a pass must be provided, otherwise the option should be given no further consideration:

- Horse-drawn vehicles are **known** to operate on the section of highway being considered for a 2+1 roadway pilot project:
  - If yes, receives a fail,
  - if no, receives a pass

5.5.4 Agricultural Vehicle Traffic

Where a municipality has initiated a Slow-Moving Farm Vehicle safety program on roads under their jurisdiction, provincial highways within that area may be included under this program. These areas are typically documented and signed and have significant safety implications that must be reviewed prior to the consideration of a 2+1 roadway system that overlaps a slow-moving farm vehicle required route.

Within these routes, farm vehicles and equipment can be expected to encroach into the through lane adjacent to the shoulder and have the potential to occupy the entire travel lane at certain locations. These routes are considered an essential link for the livelihood of many farmers. The speed differential and potential encroachment into the travel lane presents a significant safety concern when combined with a median barrier associated with a 2+1 roadway system.

Agricultural Vehicle Criterion Measurement

Where slow-moving farm vehicles are known to operate it would be considered undesirable to combine them with a 2+1 roadway system, unless adequate provisions could be provided to accommodate the slow-moving farm vehicles separately.

The following pass / fail criteria are recommended for use in determining the agriculture vehicle parameter measurement.

For a pilot project location to be considered a pass must be provided, otherwise the option should be given no further consideration:

- Agricultural vehicles are **known** to operate on the section of highway being considered for a 2+1 roadway pilot project:
  - If yes, receives a fail,
  - if no, receives a pass

5.6 Operating Considerations

The criteria discussed in this section are in relation to how the implementation of a 2+1 roadway will impact highway maintenance programs. By increasing the Roadway Platform width with the addition of a third lane, as well as the installation of a centreline median barrier, increased maintenance requirements including guide rail repairs, and winter maintenance operations, will need to be considered. The working group has recommended that consideration of the existing level of maintenance on a given section of highway be made when proposing a pilot project location.

5.6.1 Proximity of MTO Patrol Yard

This design criterion refers to the distance from the MTO Patrol Yard to the 2+1 roadway pilot area. The specific issue is how long it will take for the MTO's maintenance contractor to respond to incidents at the 2+1 roadway pilot location. Incident response is an important part of highway safety. Quickly and efficiently clearing an incident scene reduces travel delays for the highway user.

The centre median in a 2+1 roadway model could create situations where one direction of highway travel is fully blocked due to an incident such as a collision or disabled vehicle and traffic cannot get around the disabled vehicle. To avoid excessive travel delays, it is critical that MTO maintenance contractors can respond quickly to restore the flow of traffic.

Proximity to MTO Patrol Yard Criterion Measurement

- A response time greater than 2 hours receives a score of one (1)
- A response time between 1 to 2 hours receives a score of two (2)
- A response time between 0 to 1 hour receives a score of three (3)

5.6.2 Availability of Compliant Required Equipment

This design criterion refers to the MTO Patrol Yard, staffing complement and equipment availability in the proximity of the 2+1 roadway pilot area. The primary concern is the ability of the contractor to achieve the maintenance contract incident response times within the 2+1 roadway pilot location even if a patrol yard is relatively close by. Incident response is an important part of highway safety. Quickly and efficiently clearing an incident scene reduces travel delays to the highway user and reduces secondary or indirect incident occurrence potential.

Not all patrol yards have 24 hour per day, 7 day a week, 'year-round' staffing. In most maintenance contract areas, summer staffing is often reduced. It may be preferable to have the 2+1 roadway pilot close to a Patrol Yard with higher staffing levels to improve incident response times.

A related consideration is whether the existing equipment complement at the Patrol Yard is adequate to support highway operations within the 2+1 roadway pilot area. For example, will the contractor be able to maintain the 2+1 roadway pilot area with their existing winter equipment complement. If additional winter equipment is required, there will be an additional operating cost to support the improvement.

Highway maintenance standards for summer and winter maintenance are determined by the classification of highway. It is not anticipated that there will be a differing level of service for the 2+1 roadway pilot areas. The level of service will be determined by the classification of highway within which the 2+1 roadway pilot is located.

Availability of Compliant Required Equipment Criterion Measurement

The preferred location will not require a significant investment in labour and equipment to support the 2+1 roadway trial area.

The following scores are recommended for use in determining availability of compliant required equipment criteria:

- If significant additional resources (greater than $100K annually) are required to support the 2+1 roadway pilot section, the location receives a low score of one (1)
- If minimal additional resources (less than $100K annually) are required to support the 2+1 roadway pilot section, the location receives a middle score of two (2)
- If no additional resources are required to support the 2+1 roadway pilot section, the location receives a high score of three (3)

5.6.3 Location Free of Truck Inspection Stations (TIS) and/or Motor Vehicle Inspection Stations (MVIS)

This criterion refers to the number of Truck Inspection Stations (TIS) or Motor Vehicle Inspection Stations (MVIS) located within the 2+1 roadway pilot area.

TIS and MVIS are in various locations to support the MTO enforcement activities of commercial vehicles. They are important facilities that support highway safety. The location of these facilities is determined by operational needs consistent with current and future enforcement priorities.

The group has determined that the preferred pilot location is to have no TIS or MVIS within the limits of the 2+1 roadway pilot. The potential issues arising from implementing a 2+1 roadway model across a TIS or MVIS location make it impractical to recommend the model if a TIS or MVIS is within the candidate section. Issues include the presence of a median barrier impeding the movement of commercial and / or enforcement vehicles thereby restricting enforcement activities; potentially terminating the barrier in the vicinity of a TIS which is undesirable; and the proximity of the TIS to the highway creating costly modifications to the highway and or TIS to accommodate the 2+1 roadway pilot cross-section. For these reasons, it is recommended that the pilot project locations be free of any MVIS and TIS locations.

Location Free of Truck Inspection Stations and or Motor Vehicle Inspection Stations Parameter Measurement

The pass / fail is recommended for use in determining availability of compliant required equipment criteria**.**

- A Truck Inspection Station and / or Motor Vehicles Inspection Station **is/are located** on the section of highway being considered for a 2+1 roadway pilot project:
  - If yes, receives a fail,
  - if no, receives a pass

5.6.4 Location Free of Railway Crossings

The location considered for the installation of the 2+1 roadway pilot shall be free from a railway crossing to eliminate the risk and cost associated with additional lanes at these locations.

5.6.5 Geometric Standards

The criteria discussed in this section are in relation to how the overall geometric features of a highway would impact the feasibility of a proposed pilot project location. Design standards change over time and many highways that were constructed to a standard when first built can now have “substandard” elements due to the changes in standards over time. Even though these highways currently operate well, the horizontal and vertical alignment and any substandard grades, and or curves within a proposed highway section may lead to challenges when developing a pilot project. The criteria discussed in this section aim to reduce the potential impacts of areas of substandard features on a given highway section.

5.6.6 Horizontal Alignment Combined with Maximum Grades

The criterion refers to the increased collision potential of substandard horizontal curves found at the end of downgrades and how this may impact the selection of the location for the 2+1 roadway pilot.

Section 3.2.6.1 of the TAC-GDG, as modified by the MTO Design Supplement provides guidance for the design domain applicable to the horizontal alignment. The heuristics include the combination of horizontal and vertical alignment, which is of interest for this criterion.

Typically, horizontal curves should lead vertical curves; minimum standards should be exceeded, substandard horizontal curves should be avoided where operating speeds might be higher than posted or design speed (following long tangents or at the bottom of a downgrade). These grades are based upon design speeds as well as traffic volumes, measured as Average Annual Daily Traffic (AADT) and/or Design Hour Volume (DHV).

The 2+1 roadway could create situations of increased operating speeds, especially at transitions from two lanes to one. Currently, the location of these transitions is unknown. Limiting the number of potential locations of reduced conflict will provide more freedom during detailed design.

Horizontal Alignment (Maximum Grades) Criterion Measurement

The location for the 2+1 roadway pilot will be chosen from an existing two-lane undivided highway section. When assessing the suitability of existing two-lane undivided sections, the combination of a substandard horizontal curve at the bottom of a 6% or higher downgrade should be flagged and ranked accordingly.

The following scores are recommended for use in determining horizontal and vertical alignment maximum grade criteria:

- If there more than 2 occurrences of substandard horizontal curves (at the bottom of 6% or higher downgrades) within a proposed highway section, the location receives a score of one (1)
- If there are 2 occurrences of substandard horizontal curves (at the bottom of 6% or higher downgrades) within a proposed highway section, the location receives a score of two (2)
- If there are 0-1 occurrences of substandard horizontal curves (at the bottom of 6% or higher downgrades) within a proposed highway section, the location receives a score of three (3)

5.6.7 Horizontal & Vertical Curvature of a Highway (Minimum Curves)

The criterion refers to the standards for horizontal (radii) and vertical alignment (K-values for crest and sag curves) and how the presence of substandard elements may impact the selection of the location for the 2+1 roadway pilot.

For this criterion, the presence of substandard features is considered individually. For the combined effect of horizontal and vertical alignment, refer to the ‘Horizontal Alignment Combined with Maximum Grades’ criterion.

Chapter 3 of the TAC-GDG, as modified by the MTO Design Supplement provides guidance for the alignment and lane configuration. In particular, Appendix B of the MTO Design Supplement summarizes all Geometric Design Standards used for the design of provincial highways.

Horizontal Alignment (Maximum Grades) Criterion Measurement

The 2+1 roadway could create situations of increased operating speeds, especially at transitions from two lanes to one. Currently, the location of these transitions is unknown. Limiting the number of potential locations of reduced safety will provide more freedom during detailed design.

The following scores are recommended for use in determining horizontal and vertical alignment of a highway minimum grade criteria**:**

- If there 9 or more occurrences of substandard curvature features within a proposed highway section, the location receives a score of one (1)
- If there are 5 - 8 occurrences of substandard curvature features within a proposed highway section, the location receives a score of two (2)
- If there are 0 - 4 occurrences of substandard curvature features within a proposed highway section, the location receives a score of three (3)

6.0 Prioritization of Site Selection Criteria

This section of the report discusses the prioritization of each site selection parameter. While all the parameters will provide important and beneficial information that will be used to determine a feasible 2+1 roadway pilot project location, the group noted that certain parameters were more vital to consider than others. As part of this workshop, the Working Group completed a pairwise comparison of the site selection parameters to establish a priority ranking to be utilized during the site selection process. A pairwise comparison is a value analysis tool that compares different options against one another and aids in determining prioritizations amongst respective inputs. It is completed by comparing each input against one another to determine which is most desirable. Once completed, the input which was chosen over all others is determined to be the most important. For this project, the overarching site selection parameters were compared against each other. The result of the pairwise comparison is shown below in the following tables:

Table 1: Pairwise Comparison Identification Legend of Site Selection Parameters

Identification Letter	Parameter Category
A	Traffic Operating Characteristics
B	Existing Highway Safety Performance
C	Median Barrier Continuity
D	Minimize Widening Issues
E	Reduce or Eliminate Adjacent Traffic

F	Operating Considerations
G	Geometric Standards

Table 2: Pairwise Comparison of Site Selection Parameter Categories

	A	B	C	D	E	F	G	Total Votes	Percentage (%)
A		A	A	A	A	A	A	6	34%
B			B	B	B	B	B	5	26%
C				C	E	F	G	1	5%
D					E	F	D	1	5%
E						E	E	4	10%
F							G	2	10%
G								2	10%

Table 3: Site Selection Criteria Prioritization Ranking

Parameter Category	Weighted Ranking
Traffic Operating Characteristics	34%
Existing Highway Safety Performance	26%
Reduce or Eliminate Adjacent Traffic	10%
Operating Considerations	10%
Geometric Standards	10%
Median Barrier Continuity	5%
Minimize Widening Issues	5%

The results of this comparison indicate that, based on the professional opinion of the working group members, the most important considerations when determining a pilot project location are the Traffic Operating Characteristics, followed closely by the existing Highway Safety Performance. This coincides with the potential benefits that 2+1 roadways offer, being capacity and safety improvements. This shows that the most important factor in determining a potential project location is identifying areas that would see the greatest operational and safety improvements where a passing lane is warranted.

The next most important factor is to Reduce or Eliminate Adjacent Traffic by ensuring adjacent traffic is either not present or is properly separated from the higher speed traffic. This makes sense as well, as attention to these vulnerable road users will directly impact the overall safety of the proposed highway section. Ensuring this type of traffic is accounted for will directly impact the overall success of the 2+1 roadway pilot project location.

The Proximity to Maintenance Amenities and the Geometric Standards are the next parameters in terms of importance when comparing the weighted rankings against each other. While important, both parameters have options available to address any potential deficiencies such as adding maintenance staff or equipment to handle increased maintenance requirements. For this reason, ranking them lower in priority is appropriate.

Lastly, minimizing barrier drop locations and minimizing widening issues are the lowest ranked parameters. These both have alternatives to address deficiencies. These options include reinstating the existing two-lane highway cross-section where widening ability is limited. Although this option would reduce the effectiveness of the overall 2+1 roadway pilot project, it would not fundamentally prevent a pilot location from being feasible.

6.1 Weighted Rankings of Site Selection Criteria

As detailed in Section 5 of this report, each site selection parameter has been broken down into individual criteria which each play an important role in determining the overall feasibility of a potential 2+1 roadway pilot project location.

In order to determine the overall feasibility of a potential site, each of the seven primary site selection parameters were discussed to determine how much weight should be applied to each of the criteria within the parameter. These discussions revolved around determining how a potential 2+1 roadway site would be impacted by each criterion within the site selection parameter. The criteria were than compared to the associated impacts of all other criteria in said parameter and assigned a percentage value according to the importance of the criteria.

For example, one of the site selection parameters is Traffic Operating Characteristics. This site selection parameter has the criteria Volume, Speed and Passing Lane / Truck Climbing Lane Warrant. The group discussed the impacts of each of these criteria and determined a percentage weighting for each criterion. In this case, the Passing Lane / Truck Climbing Lane Warrant was determined to be the most important criteria and assigned a weighting of 50% while Volume and the Speed criterion were assigned percentages of 30% and 20% respectively.

Once the percentage weighted ranking of each criterion within an overarching parameter was determined, then the overall site feasibility weighted ranking was calculated by multiplying the overarching Site Selection Parameters Weighting by the Site Selection Criteria Weighted Ranking. For the above-noted example the Passing Lane / Truck Climbing Lane criteria represents 50% of the value of the Traffic Operating Characteristics Weighted Ranking of 34%, resulting in an Overall Site Feasibility weighted ranking of 17 %.

The resulting weighted rankings of these discussions are summarized in the table below:

Table 4: Site Selection Criteria Prioritization Summary

Site Selection Parameter	Site Selection Parameter Weighted Ranking	Site Selection Criteria	Site Selection Criteria Weighted Ranking	Overall Site Feasibility Weighted Ranking
Traffic Operating Characteristics	34%	Volume	30%	10.2%
		Speed	20%	6.8%
		Passing Lane/Truck Climbing Lane Warrant	50%	17%
Existing Highway Safety Performance	26%	Consideration of Safety Improvements Implemented	5%	1.3%
		Total Number of Expected Equivalent Property Damage Only (EPDO) Collisions	55%	14.3%
		Collision Impact Type	35%	9.1%
		Wildlife Collisions	5%	1.3%
Minimize Barrier Drops	5%	Minimize Intersections	65%	3.25%
		Minimize Entrances	35%	1.75%
Minimize Widening Issues	5%	Minimize Structures (Bridges)	40%	2%
		Minimize Structures (Structural Culverts)	10%	0.5%
		Complexity of Grading	40%	2%
		Minimize Variable Message Signs (VMS) & Road Weather Information Systems (RWIS) Locations	10%	0.5%
Reduce or Eliminate Adjacent Traffic	10%	Cycling Traffic	100%	10%
		Horse-Drawn Vehicles	If present, site not to be considered	-
		Agricultural Vehicle Traffic	If present, site not to be considered	-

Proximity to Maintenance Amenities	10%	Proximity of MTO Patrol Yard	70%	7%
		Availability of Compliant Required Equipment	30%	3%
		Location Free of Truck Inspection Stations (TIS) And/or Motor Vehicle Inspection Stations (MVIS)	If present, site not to be considered	-
Geometric Standards	10%	Horizontal Alignment (substandard at end of downgrades) (Maximum Grades)	50%	5%
		Horizontal & Vertical Curvature of a Highway (Minimum Curves)	50%	5%

These weighted percentages will be applied against the scores provided for each parameter discussed in Section 5 of this report to determine an overall site feasibility. The top sites will be investigated further by the working group to determine a ranked listing of potential sites.

7.0 Additional Considerations for Pilot Project Feasibility

This section discusses additional features and characteristics of potential sites that need to be documented along with the above-mentioned parameters. While these additional considerations are not as vital to a successful pilot project location determination, the group discussed how these nuances will assist in the final review process of the top contender sites and allow for differentiation between similar candidate sites.

7.1 Pilot Project and Passing Opportunity Lengths

When considering the implementation of a pilot project for a 2+1 roadway model, consideration must be given to the highway section length. A shorter section may not offer sufficient opportunity to review the 2+1 roadway model and the various attributes associated with this type of roadway system. To fully evaluate the 2+1 roadway, it would be essential to incorporate a few transitions from passing lanes in one direction to the opposite direction of travel as well as some barrier drops at intersections or entrances. This may be difficult to achieve on a short section.

A very long pilot location with associated higher costs could potentially reduce the cost benefit ratio and therefore overall feasibility of a potential pilot location.

Considering the above, the working group has determined the optimal pilot project length to be 8-16 km in total length. Optimal passing opportunity lengths are considered to be 1.5 – 2 km based on MTO experience from passing lane application and consideration of what is used in other jurisdictions. This optimal length provides a minimum of 2 passing opportunities for each direction of travel within the pilot project length. This distance also provides adequate room to capture some of the unique features of a 2+1 roadway as mentioned within this report.

When considering the absolute minimum and maximum lengths for a single direction passing lane within the 2+1 roadway, the limits are recommended to be between 800 m and 4 km, based on the experience of jurisdictions where 2+1 roadway has been implemented. This would be determined by the conditions and geometrics found at sites identified for further investigation based on site selection criteria.

During the study review, it was recommended that the optimal 2+1 roadway section length of 8 to 16 km identified should not prevent consideration of locations outside these limits that may lend to a successful 2+1 roadway application. Such circumstances may arise from retro fitting an existing passing lane highway section that would allow utilization of the existing widened platform if there are other realized benefits. If a proposed candidate section falls outside this optimal length, justification for its consideration and reasoning for the increase/decrease in length must be presented to the working group for review.

7.2 Stakeholder Consideration

Given that a 2+1 roadway model is a new entity for Ontario highways, an education plan for the public must accompany this pilot project initiation. More specifically, impacted partners and stakeholders where a pilot project location is being proposed must be considered and accommodated where necessary. As such, the group has decided that the highest ranked highway sections from each area across the province are to be accompanied by a list of all known stakeholders for the given section of roadway. These will include but are not limited to Ontario Provincial Police, Emergency Medical Services, Fire Departments, School Boards, Bussing Companies, Utilities, Commercial Property Owners, Residential Property Owners, Municipalities, and Recreational Clubs and Trail Providers (such as OFSC).

This list of impacted stakeholders will also assist in determining a prioritized ranking of potential sites once the initial feasibility scores are calculated. Should two sites have very similar feasibility scores, but one has the potential to impact more stakeholders, it may be recommended to use the site with less potential impacts for the purposed pilot project.

7.3 Illumination Consideration

The application of a 2+1 roadway resembles the current application of a passing lane and or a truck climbing lane. MTO does not currently specify the implementation of illumination for these situations. For the purpose of implementing a pilot location, consideration should be given to the need for illumination to help motorists distinguish between a 2+1 roadway section and a regular passing lane / truck climbing lane.

It is possible that intersections within the 2+1 roadway may require illumination at that specific location. Intersections that are to be considered for illumination should be reviewed to determine need.

7.4 Signing Consideration

Traffic signing requirements for 2+1 roadway application are similar to passing lane / truck climbing lane requirements and are available within the Ontario Traffic Manuals. Consideration should be given to the need for sign type revision or addition to help motorists distinguish between a 2+1 roadway section and a regular passing lane / truck climbing lane.

8.0 Summary

This report represents the collective findings of the 2+1 Advancement Working Group and provides recommendations for determinative parameters for potential 2+1 roadway pilot project locations. This report is to be used in conjunction with the 2+1 Feasibility Calculation Table as shown in Appendix B, to allow provincial area staff to propose candidate sites for the group to review in more detail. Using the additional considerations discussed in Section 7 of this report, along with the feasibility scores from the above-mentioned table, the Working Group will develop a prioritized list of candidate sites. for senior management consideration.

The next phase of work will entail taking the highest-ranking potential sites derived from the site selection criteria and reviewing those sites against the applicable geometric design standards for the given roadway section. A preliminary cost estimate will then be developed, and a benefit cost analysis undertaken to aid in determining a final recommended location for the pilot.

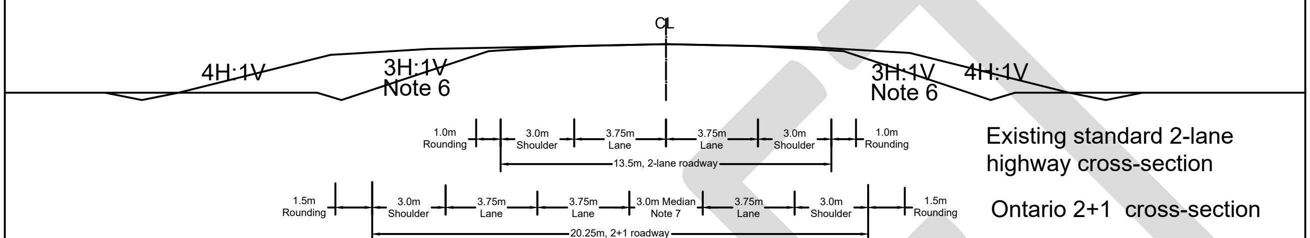
9. Appendix A

Appendix A - 2+1 Cross-Section Comparison

Assumptions:

King's Highway with high AADT and high % comm.	King's Highway with low AADT and low % comm.
Design Speed = 110 km/h	Design Speed = 100 km/h
AADT = 10,000 vpd, 12% comm.	AADT = 3,800 vpd, 8% comm.
Existing ROW = 50 m	Existing ROW width = 50 m
Standard lane width = 3.75 m	Standard lane width = 3.5 m
Standard shoulder width = 3.0 m	Standard shoulder width = 2.5 m
Desirable rounding width = 1.5 m	Desirable rounding width = 1.5 m
Rolling, tangent	Rolling, tangent
Fill height: ranges from 2 m to 4 m	Fill height: ranges from 2 m to 4 m
SBGR deflection = 1.6 m (AASHTO MASH TL-3)	SBGR deflection = 1.6 m (AASHTO MASH TL-3)

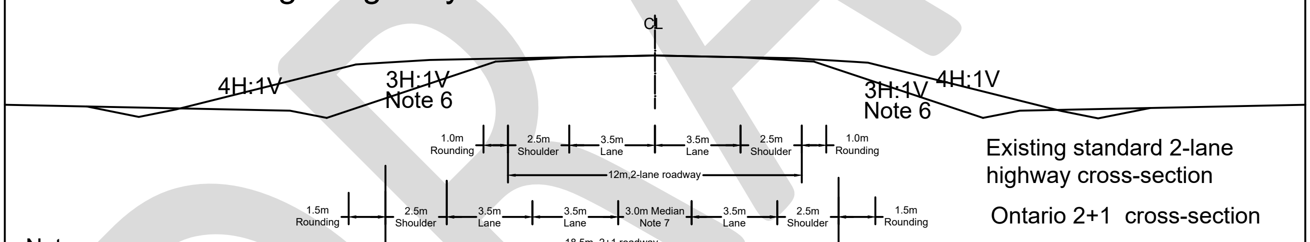
King's Highway with high AADT and high % commercial



Notes:

1. Widening is required on both sides.
2. Distance from edge of shoulder to edge of shoulder goes from 13.5 m to 20.25 m.
3. Crown elevation is retained; centreline is retained.
4. Refer to the Roadside Design Manual for desirable foreslopes and backslopes for different fill and cut height and material.
5. Pavement structure reconstruction is anticipated. Drainage, embankment settlement and frost heave issues need to be considered.
6. Foreslopes and backslopes steeper than required may exist.
7. A 3.0 m median width is required for SBGR barrier deflection.
8. If fill height is greater than 2 m and existing ROW is 50 m, cross section may not fit on existing ROW.

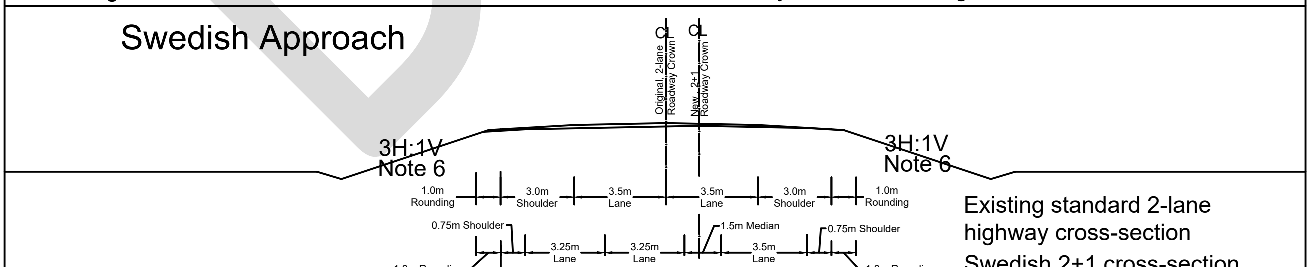
King's Highway with low AADT and low % commercial



Notes:

1. Widening is required on both sides.
2. Distance from edge of shoulder to edge of shoulder goes from 12.0 m to 18.5 m.
3. Crown elevation is retained; centreline is retained.
4. Refer to the Roadside Design Manual for desirable foreslopes and backslopes for different fill and cut height and material.
5. Pavement structure reconstruction is anticipated. Drainage, embankment settlement and frost heave issues need to be considered.
6. Foreslopes and backslopes steeper than required may exist.
7. A 3.0 m median width is required for SBGR barrier deflection.
8. If fill height is 3 m or greater and existing ROW is 50 m, cross section may not fit on existing ROW.

Swedish Approach



Notes:

1. No widening (13.0 m roadway and slopes are retained).
2. Adding a lane and a flush median is accomplished by sacrificing lane, shoulder, rounding and median widths.
3. The centreline moves and the new crown is slightly lowered to minimize or eliminate widening.
4. The asphalt and granular base layers are anticipated to be removed and replaced.
5. Barrier deflection encroaches onto opposite lane(s).

10.0 Appendix B

2+1 Feasibility Calculation Table

Location Information	Region		
	Highway		
	Length (km)		
	Starting Location	Township	
		Chainage	
		Description	
	Ending Location	Township	
		Chainage	
		Description	
			WEIGHTED SCORE
Traffic Operating Characteristics	Passing Lanes / Truck Climbing Lanes Warrant		PASS/FAIL
Reduce or Eliminate Adjacent Traffic	Horse-Drawn Vehicles or Agricultural Vehicle Traffic		PASS/FAIL
Proximity to Maintenance Amenities	Location Free of Truck Inspection Stations and or Motor Vehicle Inspection Stations		PASS/FAIL
Railway Crossings	At-Grade Railway Crossing Present		PASS/FAIL
Traffic Operating Characteristics	Posted Speed		
	Volume		
	Intermediate Step for 4 Laning		
Reduce or Eliminate Adjacent Traffic	Cycling Traffic		

Existing Highway Safety Performance	Intermediate Steps Taken (Trial of Lesser Options)		
	Total Number of Expected Equivalent Property Damage Only (EPDO) Collisions		
	Collision Impact Type		
	Wildlife Collisions		
Minimize Barrier Drops	Minimize Intersections		
	Minimize Entrances		
	Minimize Structures (Bridges)		
	Minimize Structural Culverts		
	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)		
	Horizontal & Vertical Curvature of a Highway (Min Curves) (Maximum Grades)		