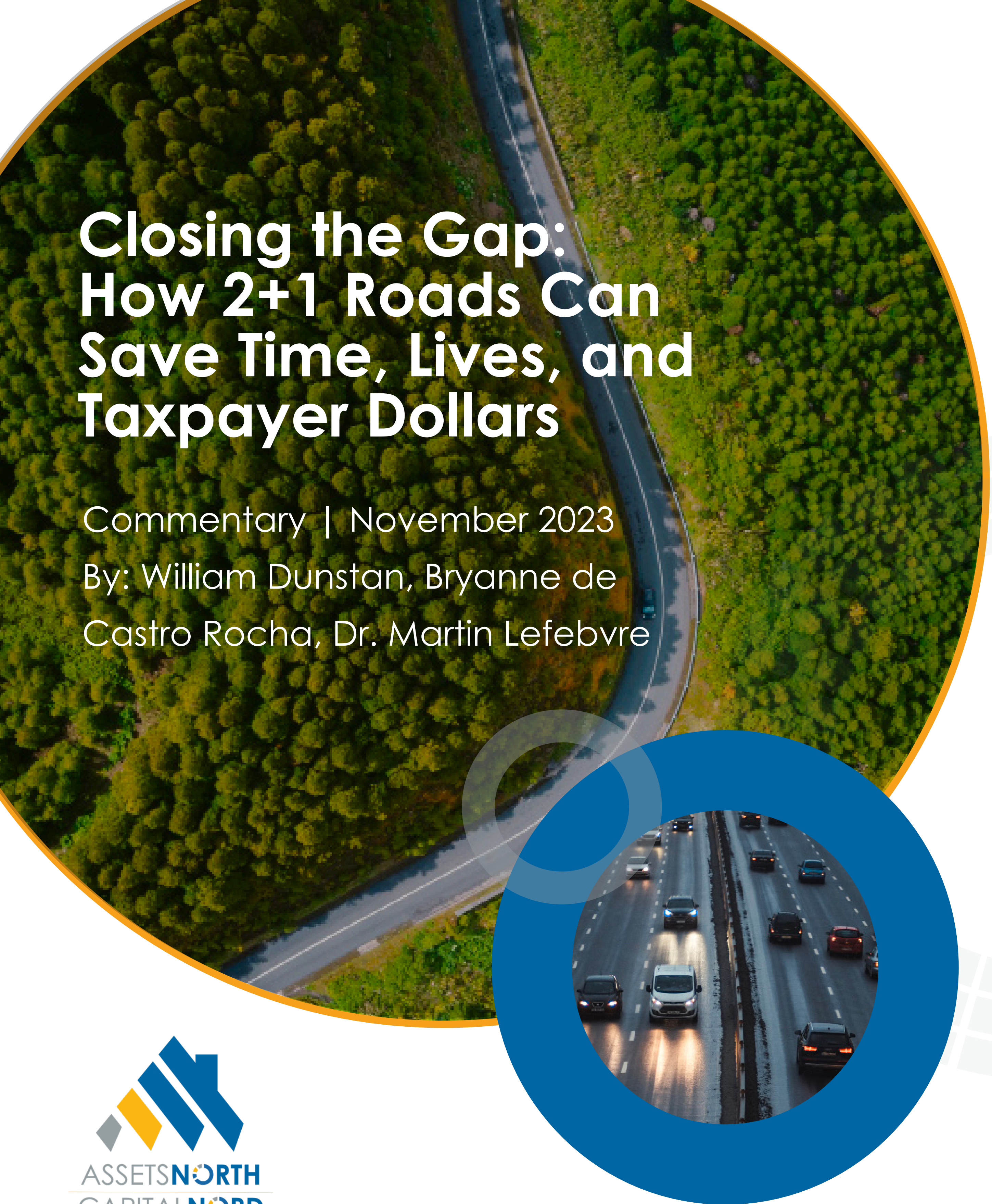

Closing the Gap: How 2+1 Roads Can Save Time, Lives, and Taxpayer Dollars

Commentary | November 2023

By: William Dunstan, Bryanne de Castro Rocha, Dr. Martin Lefebvre

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Executive Summary

The highway network in Northern Ontario plays a vital social and economic role. Yet it consists primarily of two-lane roads. Such roads limit passing opportunities and produce high rates of serious and fatal collisions, especially on major roads with high traffic volumes. The typical approach to resolve these issues has been twinning – creating a four-lane road by building an additional road platform alongside the existing one.

The question is, though – is twinning the most cost-beneficial approach? The findings of this paper reveal that compared to the 2+1 road model, the answer is no.

2+1 roads offer a favourable benefit-cost ratio, with substantial benefits and limited costs. For example, upgrading one stretch of two-lane road on Highway 11 between North Bay and Temiskaming Shores to a 2+1 configuration would deliver a benefit-cost ratio of 1.01 after 20 years, 2.20 after 40 years, and 3.64 after 60 years. Any value of 1 or higher means a project is worthwhile.

These roads comprise three-lane roads with one lane in each direction and a passing lane alternating direction every few kilometres. Globally, 2+1 roads usually include, but do not always include, a median barrier to divide traffic. Our analysis indicates that 2+1 roads in Northern Ontario should include this median barrier.

They address the major shortcomings of two-lane roads at a relatively low cost. They provide regular passing opportunities and a median barrier, significantly reducing dangerous head-on collisions. 2+1 roads also reduce delays for motorists. Fewer drivers become stuck behind slow-moving vehicles as they are able to pass, and roads are closed less often because there are fewer collisions. Finally, 2+1 roads cost less than highway twinning since they can be built entirely on the existing platforms used for two-lane roads.

If introduced in Northern Ontario, 2+1 roads will save lives. They will also improve Northerners' access to other communities and strengthen national supply chains. As they achieve these benefits at a relatively low cost, this paper recommends that 2+1 roads be implemented widely across the Northern highway network. Specifically, 2+1 roads should be put in place on an expedited basis (with a timeline of 5-10 years) in the following areas:

- Most two-lane highways with annual average daily traffic of between 3,000 and 20,000 vehicles;
- Several sections of the Northern Ontario highway network including (1) Highway 17 from Mattawa to Sault Ste. Marie, (2) Highway 11 from North Bay to slightly west of Hearst, and (3) Highway 17 and 17A from the junction of Highways 17 and 72 to the Manitoba border.

Using costing guidelines from Ontario's Ministry of Transportation, it is estimated that upgrading these roads to a 2+1 configuration would cost approximately $1.5 billion.

Introduction

Highways connect people to communities, services, and economic and recreational opportunities. Gaps in the highway network throughout Ontario's northern, central, and western regions (the regions commonly referred to as "Northern Ontario"), therefore, represent gaps in access to such opportunities. These gaps do not only, or indeed primarily, exist in the form of an absence of roads. Road inadequacies that compromise the speed and safety of transportation should also be understood as 'gaps' that need closing. Notably, most of the highway network in the regions that make up Northern Ontario consists of two-lane roads that offer few safe passing opportunities. Consequently, this highway network sees many serious collisions, road closures, and delays for motorists.

It is critical to close these gaps, but not at any cost. Government resources are not limitless. Solutions that deliver a favourable benefit-cost ratio are preferable to those that do not. A benefit-cost ratio measures the relative costs and benefits of a proposed project. When benefits exceed costs, the ratio is greater than 1 or 'favourable,' and the project can be considered fiscally prudent to pursue. Traditionally, two-lane highways in Ontario have been upgraded through twinning. But twinning is very costly. As a result, a highway may be too busy to be a two-lane road but not busy enough for twinning to offer a favourable benefit-cost ratio. An alternative road design exists, however, that offers similar benefits to twinning at a lower cost: 2+1 roads. This commentary assesses the feasibility of 2+1 roads in the regions of Northern Ontario.

Given average traffic volumes on these roads, a 2+1 road offers a better benefit-cost ratio than twinning on nearly the entirety of the highway network in every region of Northern Ontario. This does not mean that all two-lane roads should be upgraded to a 2+1 configuration. Many roads in these regions should remain two-laned. Nevertheless, it would be worthwhile to introduce 2+1 roads on parts of highways 6, 11, 17, and 101.

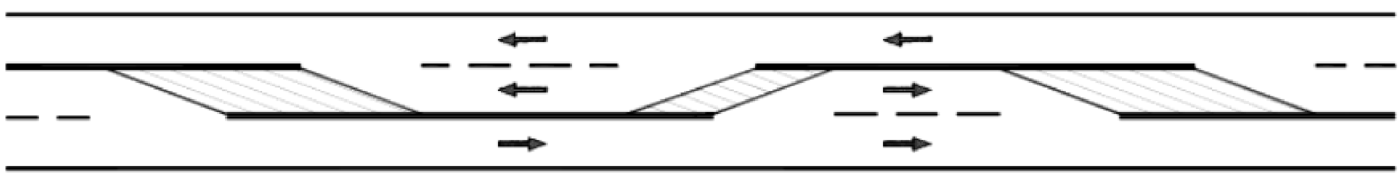
Two-lane roads, twinning, and 2+1

Two-lane roads have one lane in each direction, usually with no median barrier separating them. Additional passing lanes are intermittent or non-existent. Those that do exist appear more frequently on heavily travelled segments, some of which, such as the northern end of Highway 69 immediately south of Sudbury, consist of four lanes.

When upgrading two-lane sections, Ontario has favoured 'twinning' (Ministry of Northern Development and Mines 2017, 3-4). Twinning upgrades a two-lane road to a divided four-lane road by constructing a second road parallel to the existing one. This type of upgrade is generally associated with a high cost and a long completion time.

A 2+1 road—as illustrated in Figure 1—is a three-lane road consisting of two lanes in one direction and one lane in the other. The lane directions alternate every few kilometres and are usually separated by a barrier. Regular passing lanes within a 2+1 configuration address the significant issues related to two-lane roads: drivers stuck behind slow-moving traffic due to the lack of passing opportunities and, more significantly, dangerous head-on collisions when drivers enter the opposite lane to attempt a pass.

Figure 1: Schematic of a 2+1 roadway



Source: WSP (2019).

The Government of Ontario plans to trial the 2+1 configuration in the coming years. In December 2021, the Minister of Transportation announced that a 2+1 pilot project would be conducted on part of Highway 11 between North Bay and Temiskaming Shores. Two sections of Highway 11 – both roughly 15 kilometres in length – have been identified as the top potential locations for the pilot, and one of these locations is set to be officially selected soon (Ministry of Transportation Ontario 2021a, 11). Based on available global evidence, these pilots should be expedited, and planning has begun now to expand this model to underserviced and unsafe stretches of our existing highway network on a priority basis.

Should 2+1 incorporate a median barrier?

While 2+1 roads in Sweden incorporate a median barrier to divide traffic travelling in opposite directions, this is not the case in all jurisdictions. On many 2+1 roads in Germany, for instance, no physical barrier separates traffic. Including median barriers within the 2+1 configuration entails greater construction and repair costs and can lead to a greater number of minor collisions from vehicles striking the barrier. 2+1 roads with median barriers often lead to increased property damage collisions (Ministry of Transportation Ontario 2021b, 7).

Median barriers, however, offer substantial benefits in the form of reducing fatal and serious injury collisions. Put simply, it is better for a vehicle to damage a barrier than to collide head-on with another vehicle. Indeed, a 2018 benefit-cost analysis completed for MTO found that a prospective 2+1 road would likely offer a more favourable benefit-cost ratio if a median barrier was included (WSP 2019, 133). In sum, 2+1 roads introduced in Ontario should incorporate a median barrier.

Costs and benefits of 2+1

2+1 roads promise a favourable benefit-cost ratio by achieving significant benefits, primarily in the form of improved safety, at a relatively low cost. In Sweden, the 2+1 configuration has demonstrated similar or superior safety performance to divided highways (Going the Extra Mile for Safety 2019, 20; Ministry of Transportation Ontario 2021b, 7). Upgrading two-lane roads to a 2+1 configuration in Sweden reduced fatal and serious injury collisions by 50 to 80 per cent (Ministry of Transportation Ontario 2021b, 7; Vadeby 2016, 8).[1] Modelling done for Ontario's Ministry of Transportation (MTO) suggests that the application of 2+1 with a median barrier on one section of Highway 11 would reduce such collisions by approximately 40 per cent (WSP 2019, 128).[2,3] The 2+1 design appears to work well on roads with an annual average daily traffic (AADT) rate as high as 20,000 (Going the Extra Mile for Safety 2019, 7).[4] For reference, AADT on most sections of highways 11 and 17 falls well below 20,000 (Ministry of Transportation Ontario 2016, 10-18). Some of these roads have been twinned in recent years (IBI Group 2016, 24). But given their traffic volumes, these roads could have benefited from a 2+1 configuration instead.

The cost savings relative to twinning stem from the fact that a two-lane road can typically be upgraded to a 2+1 configuration while using the existing road platform (Going the Extra Mile for Safety 2019, 6). Using an existing platform reduces land costs and lowers the project's environmental impact. For similar reasons, 2+1 represents a faster option for closing gaps in the highway network than twinning. In most cases, the time required to add passing lanes and install median barriers on an existing road platform is less than the time needed to build an additional road platform. The possibility of a faster upgrade to 2+1 means that these roads can decrease the number of fatal and serious injuries sooner, thus saving more lives. Additionally, where traffic levels are growing but have not reached a level sufficient to justify twinning, 2+1 roads can be a cost-effective intermediate upgrade, allowing for twinning to occur at a future date if and when traffic levels justify the investment (Ministry of Transportation Ontario 2021b, 14).

All factors above contribute to the lower cost of 2+1 roads. According to a Swedish report, 2+1 saves one life per $150,000 spent, compared to one life per $4.5 million for highway twinning (Going the Extra Mile for Safety 2019, 5).

[1] Sweden has implemented other safety measures in addition to 2+1 roads. These measures also contribute to fewer fatal accidents (MTO 2021b, 7).

[2] The net effect of introducing a median barrier on safety performance is positive. However, it should be noted that these barriers can increase traffic driving in the wrong direction and represent a safety concern in areas where the number of collisions with wild animals is high (MTO 2021b, 8, 19)

[3] The use of median barriers has been certified according to Manual for Assessing Safety Hardware (MASH) regulations and approved in Ontario since the publication of the WSP 2019 report (MTO 2021b, 9)

[4] Annual average daily traffic is calculated as the total volume of vehicle traffic during a year, divided by 365.

Benefit-cost analysis of 2+1

In 2019, an operational performance review was conducted for MTO of a section of Highway 11 stretching from the City of North Bay to the Highway 558 junction near Temiskaming Shores (WSP 2019). That report explored the feasibility of upgrading a section of highway from a two-lane configuration to 2+1. As part of this discussion, WSP completed a cost-benefit analysis (CBA) for the potential upgrade. This analysis estimates that the benefit-cost ratio for transforming the existing road into a 2+1 road with a median barrier would be 0.36. In other words, the project would deliver $0.36 in safety-related benefits for every $1 spent on construction (ibid., 133). The benefit-cost ratio should be at least 1 for a project to be financially worthwhile.

If the assumptions underlying the initial analysis are reviewed, the benefit-cost ratio increases considerably to at least 1.01, with a medium value of 2.20 and up to 3.64. The first assumption refers to collision costs. In the previous study, values assigned to saving a life and preventing serious injuries were lower than those recommended by most CBA guides. The collision costs previously used were: $1,582,000 for a fatal accident, $142,000 for a severe injury accident, $53,000 for a moderate injury accident, $36,000 for a slight injury accident, and $8,000 for a property damage-only accident (WSP 2019, 131). Most CBA guides recommend using greater values. For instance, British Columbia's Ministry of Transportation and Infrastructure uses the following values: $8,087,204 for a fatal crash, $302,636 for an injury crash, and $13,518 for a property damage-only crash (Apex Engineering 2018, 20). These values are higher because they include willingness to pay—the amount that people would be willing to pay for a good, or in this case, to avoid a 'bad' (i.e., a severe or fatal collision). Therefore, willingness to pay should be included in addition to more tangible direct and indirect costs when estimating the value that society places on improved road safety.

The second assumption was the devaluation of benefits. Benefits received in the future from improved road safety were devalued at a higher percentage than needed. The previous analysis applied a 4.5 per cent compounding annual discount rate to benefits experienced after the first year, but it did not allow for inflation in calculating the dollar value to be discounted. The analysis valued a life saved both today and twenty years from now at $1,582,000. But if, as the application of a discount rate suggests, the value of money erodes over time, then the dollar value of preventing a collision should increase in future years. Alternatively, the dollar value of preventing a collision can be held constant, but in that case, no discount rate should be applied against those benefits since inflation will discount the value of a fixed dollar amount over time. An alternative reason for applying a discount rate is that people often show a preference for experiencing benefits today over experiencing benefits in the future. This may be true at the level of an individual, but it does not apply to societies across generations. It is reasonable to say, for example, that a typical individual would prefer to receive one pencil today in place of receiving an identical pencil twenty years from now. It is not reasonable to say that motorists in the future will value their lives less than motorists today. Discounting the value of future collisions would mean that, for the calculation, the lives and health of future drivers are worth less than those of today.

The years used for dollar figures was the third assumption to be reviewed, which is somewhat similar to the second revision above. Different dollar years for costs and benefits were previously used. While construction costs were estimated using MTO guidelines from 2016 (WSP 2019, 129), benefits—i.e., collision costs avoided—were calculated using figures from 2012 (WSP 2019, 72-73). Using construction costs from a later year underestimates benefits, as inflation between 2012 and 2016 was not accounted for on the benefit side. A benefit-cost analysis should use cost and benefit values from the same year. One can derive 2016 benefit values from the British Columbia values mentioned above for preventing collisions by deflating the 2018 dollar values cited earlier to 2016 dollar values. The values used in British Columbia were initially set in 2007 and then increased according to CPI (Consumer Price Index) inflation to establish values for 2018. According to the Bank of Canada (2022), CPI deflation between 2018 and 2016 was -3.66 per cent. Accordingly, the 2018 values—$8,087,204 for a fatal crash, $302,636 for an injury crash, and $13,518 for a property damage-only crash (Apex Engineering 2018, 20)—should be deflated by 3.66 per cent. Therefore, in 2016 dollar values, preventing a fatal crash is worth $7,790,814, an injury crash is $291,555, and a property damage-only crash is $13,026.

Finally, the project assessment period was also relatively short. The analysis assessed the project over 20 years, but industry standards for lifespans used in CBAs are as high as 60 years. In fact, the CBA completed for the proposed return of Ontario Northland (2022) rail service between Toronto and Timmins used a 60-year lifespan. The period used in CBAs for transportation projects can influence results because construction costs are concentrated at the beginning of most projects' lifespans, while benefits tend to be relatively constant throughout.

Therefore, using different assumptions, a reviewed analysis of the proposed 2+1 upgrade to part of Highway 11 would assign greater values to fatalities and injuries prevented, not apply a discount rate, use 2016 dollar values for benefits, and be extended over a longer lifespan.

If no discount rate is applied and British Columbia's valuations for accidents prevented are used, the benefit-cost ratio for the project over 20 years is **1.01**. Using a project lifespan of 40 years, the same methodology delivers a benefit-cost ratio for the 2+1 upgrade of **2.20**, and that number rises to **3.64** over 60 years.[5] In essence, using assumptions more in line with usual CBA practice, upgrading the section of Highway 11 to a 2+1 configuration would have been shown to be of significant fiscal benefit.

In 2021, MTO published new cost estimates for implementing 2+1. To determine how these updated cost estimates impact the case for 2+1, this commentary includes a second CBA that uses those new figures. MTO (2021a; 2021b) estimates that upgrading a two-lane road to a 2+1 configuration would cost 0.5 million to 2 million dollars per kilometre, depending on the complexity of each location. Upgrading an existing three-lane section—i.e., a location with a passing lane—would cost $500,000/km. A location where the existing road platform is used or where only routine grading is needed is estimated to cost $1 million/km to upgrade. An area that allows for a mix of routine grading and no extreme deep fills of water bodies is estimated to cost $1.5 million/km to upgrade. If a stretch of road has deep swamps or water bodies, complex parallel drainage, unsuitable soils, and rock cuts, it is estimated to cost $2 million/km to upgrade. A simple GIS desktop exercise was used to find the areas that would need the various tiers of upgrading.[6]

If one uses these costs from 2021, however, it is important to update the valuations for benefits used earlier in this commentary using CPI inflation to not underestimate benefits.[7] According to the Bank of Canada (2022), CPI increased by 6.26 percent between 2018 and 2021. Accordingly, the 2018 valuations cited earlier for fatal, injury, or property damage-only crashes should be increased by 6.26 percent.

Using the MTO 2021 cost and benefit values, a 2+1 upgrade delivers a benefit-cost ratio equal to or greater than 1 after 21 years (1.01), 2.09 over 40 years and 3.46 over 60 years. Such values are very similar to those found using the WSP (2019) cost figures and the Apex Engineering (2018) inflation-adjusted values for safety benefits (1.01 for 20 years, 2.20 for 40, and 3.64 for 60 years).[8] In sum, the benefit-cost ratio of 2+1 is favourable within a standard timeframe for assessing transportation projects under either methodology presented by this paper.

[5] The CBA conducted previously assumed a 1 per cent annual increase in traffic volumes and collision frequencies (WSP 2019, 131). In extending the analysis to 40 and 60 years, we assume a continued 1 per cent increase in traffic volumes and collision frequencies. Additionally, it should be noted that a 1 per cent increase in traffic volumes will likely result in an increase in collision frequencies that is greater than 1 per cent because busier roads increase opportunities for collisions between vehicles.

[6] Please refer to the appendix for a more detailed explanation of the GIS calculations.

[7] The benefit values used earlier in this commentary were taken from BC Ministry of Transportation and Infrastructure (Apex Engineering 2018). As explained earlier, those values were initially set in 2007, then increased according to CPI inflation to establish values for 2018. To derive appropriate values for 2021, the same approach of increasing values according to CPI inflation was used.

[8] It is notable that while this 2+1 upgrade delivers a benefit-cost ratio of more than 3, the business case regarding the restoration of passenger rail in Northeastern Ontario estimated a benefit-cost ratio of less than 0.5 for various versions of that project (Ontario Northland Transportation Commission 2022). This indicates that 2+1 roads are a better deal than other transportation investments that the provincial government has elected to pursue in Northern Ontario.

Other 2+1 benefits

Although reducing deaths, injuries, and property damage from collisions would be the primary benefits of transforming highways from two-lanes to 2+1, other benefits must be considered:

Value of road users' time:

Vehicle occupant time is wasted when accidents delay traffic by blocking the road. Their time is also wasted when they cannot pass slow-moving traffic. Upgrading two-lane roads to a 2+1 configuration alleviates both problems and saves road users' time. The BC Ministry of Transportation and Infrastructure values non-commercial vehicle occupant time at 50 per cent of the average wage and truck driver time at the average wage for a truck driver plus 25 per cent to account for nonwage payroll expenses (Apex Engineering 2018, 15-17). Using these figures, it becomes clear that delays are costly.

In 2021, the average hourly wage in Ontario was $30.82, and the average hourly wage in Ontario for people employed in transport and heavy equipment operation and related maintenance occupations was $24.72 (Statistics Canada 2022). Therefore, the values assigned to non-commercial vehicle occupant and truck driver time should be $15.41 per hour and $30.90 per hour, respectively. The various stretches of the section of Highway 11 assessed in the MTO review have AADT rates ranging from 3,400 to 6,200, with roughly 30 per cent of traffic consisting of trucks (WSP 2019, 4). Accordingly, for one day, if every vehicle passing through a section with an AADT rate of 4,000 was delayed by 30 minutes, the total cost of time wasted would be $44,429.[9] Similarly, if 1,200 truck drivers on highways with an AADT rate of 4,000 are delayed by six hours due to a road closure, the total cost of time wasted would be $222,480.

Calculation 1 –
4,000 AADT rate, with 30% truck traffic

Cost for commercial truck drivers:
1,200 × $30.90 × 0.5 = $18,540

Cost for noncommercial vehicle occupants (assuming 1.2 occupants per vehicle):
3,360 × $15.41 × 0.5 = $25,889

Total cost: $18,540 + $25,889 = $44,429

Calculation 2 –
1,200 trucks stuck for 6 hours

1,200 × $30.90 × 6 = $222,480

Enabling greater economic activity:

An elevated risk of severe collisions and collision-related delays on northern highways harms the economies of communities that rely on these roads. Economic development officials from communities along the Highway 11 corridor identified numerous ways unsafe roads adversely impact local economies in correspondence with the author in May 2021. They include road closures that prevent businesses from moving goods in and out of their communities, potential tourists that may not visit if they do not feel safe driving to these communities, and employee morale and productivity that can suffer if a co-worker is killed or injured while travelling on company business.

Additionally, for twinning to be possible, highways occasionally need to be diverted from communities, given the lack of horizontal space. This has the potential to adversely impact the economies and businesses of these communities (Center for Urban Transportation Research 2014, 4-5). But 2+1 roads have a smaller width and thus use less space. This reduces the potential for diversion and increases the likelihood that communities that rely on existing highways will support this alternate approach. In sum, adopting the 2+1 configuration on two-lane highways can boost nearby communities' economies by potentially maintaining existing routes and thus facilitate tourism, on-time deliveries, and improved productivity.

[9] See calculations in text box. This calculation assumes 1.2 occupants per noncommercial vehicle.

A lower number of calls to emergency services:

The main benefit of 2+1 roads for emergency services is a significant reduction in fatal and serious injury collisions that require emergency services to be deployed. The possible drawback is that a median barrier can make it more difficult for these services to access an emergency site. This drawback can be mitigated, however, by planning the emergency response direction and manually lowering cable barriers or removing parts of steel barriers to allow access. Overall, the net benefit of 2+1 roads for emergency services is positive (Going the Extra Mile for Safety 2019, 19).

Improved road visibility in winter:

In evaluating 2+1 roads, a previous report raises concerns regarding decreased visibility and deterioration of road markings during winter (WSP 2019, 134). In actuality, 2+1 roads can enhance visibility when a median barrier is installed because this improves road delineation (Yu 1971, 92) and, thus, driving conditions in winter and at night.[10]

Other costs of 2+1

Just as 2+1 roads provide benefits beyond direct safety improvements, upgrading two-lane roads to a 2+1 configuration imposes costs beyond initial construction. Annual maintenance costs would likely rise. Wider roads mean more pavement that requires snow removal and that must eventually be repaired (Ministry of Transportation Ontario 2021b, 10). Barriers need to be repaired or replaced in case of contact, which causes road blockages and delays (WSP 2019, 134). However, 2+1 roads in Sweden caused fewer traffic disturbances than other roads (Bergh et al. 2016, 343), making traffic more fluid and reducing delays (Ministry of Transportation Ontario 2021b, 11). Further, because 2+1 roads are non-existent in Ontario and are uncommon across North America, a public education campaign would be necessary to familiarize drivers with the concept (Ministry of Transportation Ontario, 2019, 135). The success of these roads in Sweden, though, has helped the 2+1 concept be accepted in other countries (Ministry of Transportation Ontario 2021b, 11).

[10] That is especially true if the median barrier is delineated with reflective devices (French 2003). The median barrier must also be kept visible in winter through snow removal to improve driving visibility (Yu 1971, 92). However, snow accumulation in Sweden tends to be a problem with barriers on the roadside, not with median barriers (Going the Extra Mile for Safety 2019, 15).

When should two-lane highways be upgraded to 2+1?

For most of the highway network in Ontario's northern, central, and western regions, 2+1 provides a better benefit-cost mix than twinning. A more challenging question is when is it worthwhile to upgrade existing two-lane roads to a 2+1 configuration?

There is some uncertainty over the precise 'cross-over point' where it becomes worthwhile to upgrade a two-lane road to a 2+1 configuration. Sweden uses the 2+1 configuration on roads with an AADT rate of at least 2,000 to 3,000 (Going the Extra Mile for Safety 2019, 7; Bergh et al. 2016, 331). The MTO, by contrast, suggests that the benefits of such an upgrade would be limited for roads with an AADT rate under 4,000 (Ministry of Transportation Ontario 2021b, 13).

The CBA, with adjusted assumptions and parameters in this commentary, concerns a stretch of Highway 11, whose various segments have an AADT rate between 3,400 and 6,200. Upgrading this stretch of Highway 11 from two lanes to 2+1 would produce a favourable benefit-cost ratio within approximately 20 years, with this ratio increasing in future years. Moreover, these figures do not account for certain additional benefits, such as the value of road users' time that is wasted when roads are closed due to collisions. If 2+1 produces such a favourable benefit-cost ratio on roads with an AADT rate between 3,400 and 6,200, there is a strong possibility that it will be worthwhile to upgrade two-lane roads with an AADT below 4,000. Additionally, AADT should not be the only consideration for identifying roads that should be upgraded to 2+1. The benefits of 2+1 will be especially pronounced on roads with high rates of serious collisions relative to traffic volumes and that are essential links in major transportation corridors.

In short, one can be reasonably confident that introducing a 2+1 configuration on two-lane roads with an AADT rate of at least 3,000 will offer a favourable benefit-cost ratio. Accordingly, two-lane highways with an AADT of 3,000 or higher should be upgraded to 2+1. Additionally, it is likely that 2+1 can offer a favourable benefit-cost ratio on some roads with an AADT below 3,000, particularly those that see many collisions or that are key transportation corridors. All sites must be assessed on a case-by-case basis, but in most cases, the costs of upgrading to 2+1 will become worthwhile at traffic volumes around 3,000 AADT.

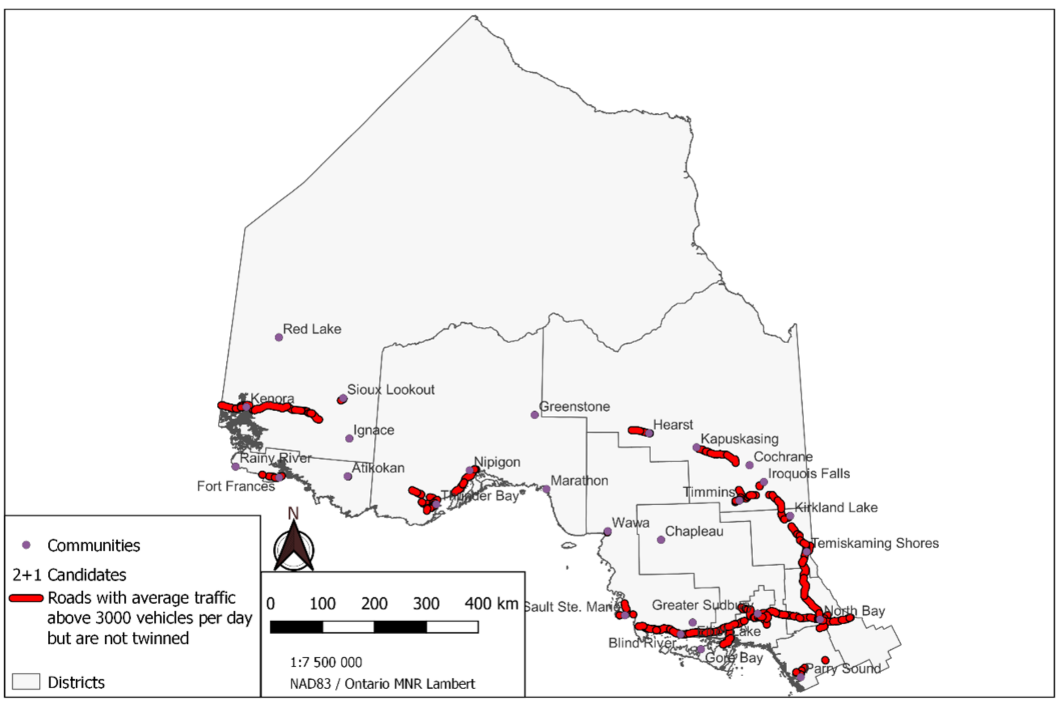
When should twinning be used in place of 2+1?

Swedish experiences suggest that 2+1 works well and outperforms highway twinning on a benefit-cost basis at traffic volumes as high as 18,000 to 20,000 AADT (Going the Extra Mile for Safety 2019, 7; Ministry of Transportation Ontario 2021b, 7). 2+1 can encounter issues at lower AADT rates in cases where peak hourly volumes exceed 1500 vehicles per hour, as might occur on roads used by the weekend or holiday traffic leaving a city for cottage country (Going the Extra Mile for Safety 2019, 7). When AADT exceeds 20,000 or peak volumes exceed 1,500 vehicles per hour, highway twinning should be done instead of a 2+1 upgrade.

Which sections of highway in Northern Ontario should be upgraded to 2+1?

If the 2+1 pilot between North Bay and Temiskaming Shores is successful, the 2+1 configuration should be introduced on other roads with suitable characteristics. The most significant characteristic of 2+1 suitability is traffic volumes. Figure 2 is a map of roads in Ontario's northern, central, and western regions, which are not twinned but for which traffic volumes exceed 3,000 AADT.[11]

Figure 2: Map of roads with AADT > 3,000 that are not twinned



Source: Authors' calculations.
Note: as of June 2022.

[11] None of these roads have an AADT rate of 20,000 or greater

This map can be used to identify candidate roads for upgrading to 2+1. There are six stretches of largely two-lane highway in Ontario's northern, central, and western regions that, given traffic volumes, are strong candidates for upgrading to 2+1. Ordered from highest average AADT to lowest, these roads are: (1) Highway 17 from Mattawa to Sault Ste. Marie, (2) Highway 101 near Timmins from the junction with Municipal Rd near Highway 11 to Porcupine, (3) Highway 17 and 17A from the junction of Highways 17 and 72 between Dryden and Sioux Lookout to the Manitoba border, (4) Highway 11/17 from Nipigon to Shabaqua Corners, (5) Highway 11 from North Bay to the junction of Highways 11 and 663 west of Hearst, and (6) Highway 6 from Little Current to Espanola. Table 1 provides an overview of these sections, their length, and their average AADT.[12]

Table 1: Primary candidate roads for upgrading to 2+1

Section	Distance	Average AADT
Mattawa to Sault Ste. Marie	430 KM	6520
Highway 101, Municipal Rd. junction to Porcupine	22 KM	4620
17/72 Junction to Manitoba	131 KM	4090
Nipigon to Shabaqua Corners	216 KM	3810
North Bay to 11/663 Junction	598 KM	3530
Little Current to Espanola	45 KM	3520

As shown in Figure 2, AADT exceeds 3,000 on nearly the entirety of these six extended sections of the highway (Ministry of Transportation Ontario 2016, 10-18). As shown in Table 1, the average AADT exceeds 3,000 for all six roads. Indeed, on much of these roads, AADT is between 4,000 and 15,000, which MTO has identified as the prime traffic volume for 2+1 (Ministry of Transportation Ontario 2021b, 13).

For various reasons, the 2+1 candidate roads do not align perfectly with the red-highlighted roads in Figure 2. Between Kirkland Lake and Hearst, AADT on much of Highway 11 is below 3,000. Nevertheless, AADT on these sections is close to 3,000. As well, these roads are critical transportation links for traffic travelling within these regions as well as across Canada, and in the event of road closures, alternative routes are limited or non-existent. Therefore, 2+1 roads are likely to prove very beneficial on these roads, and so the entirety of the route from North Bay to the Highway 11/663 junction west of Hearst should be upgraded to 2+1. Elsewhere, Figure 2 identifies a few isolated sections of road with AADT rates exceeding 3,000 that are not included in the candidate list. These sections, however, are not long enough to warrant a 2+1 upgrade.

Further, the figures in Table 1 can be used to establish priority for completing 2+1 upgrades. If limited resources require that 2+1 upgrades be completed gradually, roads with the highest AADT rates should receive upgrades first, as these upgrades will likely produce the greatest benefits. Using these guidelines, the highest priority location for upgrading two-lane roads to a 2+1 configuration should be the road from Mattawa to Sault Ste. Marie, followed by Highway 101 near Timmins. It must be noted that the average AADT on Highway 11 from North Bay to slightly west of Hearst is lowered by the inclusion of some stretches of road with AADT below 3,000. Accordingly, upgrades on that road should not necessarily be a lower priority than for the two roads in Western Ontario with higher AADT rates.

[12] The 2+1 configuration would not be used in towns or cities. For example, on the road from Mattawa to Sault Ste. Marie, the 2+1 configuration would not be used on roads inside the city of North Bay. Accordingly, the length and average AADT cited for each of these four sections excludes parts of the road that cross large towns and cities.

The cost of widespread 2+1 upgrades

The total distance of the six primary candidate roads for introducing 2+1 In Northern Ontario is 1,442 kilometres. This would represent a substantial investment. This raises the question, how much exactly would it cost to upgrade all these roads from two lanes to a 2+1 configuration?

There are two main expenses involved in introducing 2+1: maintenance and initial construction. As mentioned earlier, 2+1 roads would likely entail greater maintenance costs than the present roads. The additional pavement of the third lane must be installed, repaired, and cleared of snow. Similarly, median barriers must be installed and eventually repaired or replaced. Carlsson (2009) calculates the added costs for service and maintenance of 2+1 roads relative to two-lane roads in Sweden: $14,770 per kilometre per year, adjusting for currency conversions and inflation. As Sweden and Northern Ontario have similar physical geography, road maintenance requirements and costs are likely to be similar. Upgrading a two-lane road in Northern Ontario to a 2+1 road is calculated to require $14,770 in additional maintenance per kilometre per year. Therefore, introducing 2+1 on all recommended roads is calculated to require approximately $20 million per year in additional maintenance.

Critically, 2+1 roads remain cost-effective after accounting for the added maintenance costs. One can account for annual maintenance costs by adding them to the benefit-cost calculations that use MTO's 2021 figures (discussed earlier in this paper regarding a particular section of Highway 11; MTO 2021a; MTO2021b).[13] Doing so causes these calculations to overstate costs relative to benefits, as economic benefits and savings of motorists' time remain unaccounted for. However, even using calculations that understate benefits, a 2+1 upgrade still delivers a favourable benefit-cost ratio after 29 years, remaining financially feasible despite additional maintenance costs.

Initial construction costs will represent the bulk of the required investment to introduce 2+1 roads. The cost of upgrading all 1,442 kilometres of recommended roads was estimated using the 2021 MTO costing guidelines (MTO 2021a; MTO2021b). This represents a more conservative approach, as such guidelines tend to produce higher estimated costs than those projected previously (WSP 2019). The average terrain complexity and the average cost per kilometre were calculated for the entirety of Highways 11 and 17 using a desktop GIS exercise similar to the one described in the earlier benefit-cost analysis section. According to these calculations, the average cost of implementing 2+1 should be $1,024,655 per kilometre. Accordingly, we estimate that upgrading all primary candidate roads to 2+1 will cost roughly $1.48 billion.

[13] To do a benefit-cost analysis for a 2+1 upgrade, one needs detailed collision statistics and projections with and without 2+1. This data is only readily available for the section of Highway 11 assessed in the previous (WSP 2019) report. Therefore, the benefit-cost analyses in this commentary exclusively focus on that section of road.

But who will provide these funds? And who should provide what share? For roads that are part of the Trans-Canada Highway, both the federal and provincial governments should fund the upgrading of the proposed roads to 2+1. While transportation generally falls under provincial jurisdiction, there is a national interest in maintaining highways that are major routes for cross-Canada traffic. Therefore, the federal government often provides partial funding for upgrades to the Trans-Canada Highway (Transport Canada 2020). More than 90 per cent of the roads that this commentary recommends being upgraded to 2+1 are part of the Trans-Canada Highway, including the entirety of Highways 11 and 17. Upgrades to roads that are not part of the Trans-Canada Highway should be entirely funded by the Government of Ontario.

For roads that are part of the Trans-Canada Highway, the federal government should commit one-third of the necessary funds to upgrade these roads to a 2+1 configuration, with the province covering the rest. This would align with recent funding arrangements for similar projects. In recent years, four-laning of various sections of the Trans-Canada Highway in Ontario and British Columbia have received, on average, 33 per cent of funding from the federal government, with the province providing the rest.[14]

[14] The 2+1 figure is calculated from four official project announcements: a 2022 announcement regarding the four-laning of Highway 11/17 between Thunder Bay and Nipigon, a 2021 announcement regarding the four-laning of Highway 11/17 between Thunder Bay and Nipigon, a 2021 announcement regarding the four-laning of a stretch of highway in the Shuswap region of BC, a 2019 announcement regarding the four-laning of the highway between Glacier National Park and Golden, BC, and a 2016 announcement regarding a four-laning project near Salmon Arm, BC (Ontario 2022; British Columbia 2021; Infrastructure Canada 2019; Infrastructure Canada 2016).

Criteria for assessing Ontario's 2+1 pilot

As mentioned earlier in this piece, the Government of Ontario has pledged to conduct a 2+1 pilot project on part of Highway 11 between North Bay and Temiskaming Shores. This pilot's performance should be assessed on its effects on road safety and associated road closures. The following six indicators should be used to compare the study area's performance before and after the 2+1 pilot:

- Number of fatal collisions
- Number of serious injury collisions
- Number of moderate and minor injury collisions
- Number of property damage-only collisions
- Number of road closures due to collisions
- Duration of road closures due to collisions

It is not possible to identify a single threshold for each indicator that allows the pilot to immediately be declared a "success" or "failure. " The data for each indicator must be assessed together and balanced to arrive at a holistic judgment. That said, one can say that if the 2+1 configuration works as intended, there should be a reduction in the number of fatal collisions, the number of serious injury collisions, and the number of extended collision-related road closures.

Recommendations

2+1 roads represent a promising approach for improving the highway network in Ontario's northern, central, and western regions. If Ontario's upcoming 2+1 pilot project is successful, the 2+1 configuration should be deployed widely across these regions. The evidence presented in this commentary points to several recommendations on how this should be done:

2+1 roads should include a median barrier:

Median barriers are an inexpensive addition to the 2+1 configuration that offer significant further reductions in fatalities and serious injuries. Although the presence of a median barrier can lead to an increased number of minor collisions, this cost is outweighed by the benefit of saving many lives and reducing serious injuries.

Two-lane highways with an AADT rate between 3,000 and 20,000 should usually be upgraded to 2+1, but prospective upgrades must be assessed on a case-by-case basis:

For most two-lane roads with an AADT rate of at least 3,000, the benefits of a 2+1 upgrade are likely sufficient to fully offset the costs. On roads with an AADT rate below 20,000, 2+1 configurations offer a better benefit-cost ratio than highway twinning and likely allow for more rapid closure of gaps in the highway network. The particular features of each site, however, will drive the benefit-cost ratio up or down, making certain sections of the road more or less suitable for the implementation of 2+1. Individual site assessments must consider a broader range of costs and benefits than the initial construction costs and the direct benefits from improved road safety.

2+1 should be introduced on most sections of the following roads:

- Highway 17 from Mattawa to Sault Ste. Marie;
- Highway 101 between Timmins and Highway 11;
- Highway 11 from North Bay to slightly west of Hearst;
- Highway 11/17 from Nipigon to Shabaqua Corners;
- Highway 17 and 17A from the junction of Highways 17 and 72 to the Manitoba border; and
- Highway 6 from Little Current to Espanola.

Traffic volumes on these roads are in the appropriate range for introducing a 2+1 configuration. As these roads are also critical transportation corridors within their regions and for Canada as a whole, the benefits of 2+1 should be especially valuable.

Conclusion

Safe, fast, and reliable transportation infrastructure is critical to connecting communities, but this infrastructure is lacking in Ontario's northern, central, and western regions. Therefore, improving roads in these regions should be a priority for policymakers. While doing so, maximizing benefits relative to costs should be a guiding principle. The projects chosen for implementation should offer a meaningful return on taxpayer dollars by improving safety, reducing travel delays, and facilitating economic and social activity, among other benefits. On much of the highway network in these regions, 2+1 roads likely offer a more favourable benefit-cost ratio than two-lane roads or twinned highways. By significantly reducing fatalities and serious injuries while requiring relatively little new construction, upgrading two-lane roads to a 2+1 configuration delivers substantial benefits at a limited cost. Introducing 2+1 roads across much of Northern Ontario's highway network would cost nearly $1.5 billion; however, the evidence suggests the benefits of such upgrades would exceed these costs.

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Appendix

For this commentary's GIS exercise, Highways 11 and 17 were extracted from the Ontario Road Network (ORN) Road Net Elements file (Ontario Ministry of Natural Resources and Forestry 2017).[15] The selection was then given a 250m buffer to examine the topography surrounding the existing road. While 250m is much larger than any proposed road expansion, this size is large enough to catch terrain features where the road is being upgraded, which could possibly increase the complexity and, therefore, cost of expansion. This buffered surface area was then overlayed on the Canadian Digital Elevation Model's slope map (Natural Resources Canada 2013). The slope map is a product derived from the digital elevation model, which naturally enough gives the slope of the ground for various points of the terrain. In this case, slopes were categorized into three zones:

- Terrain with a slope of less than 20 percent
    - This would mean less than a 20m change in elevation in a 100m run
- Terrain with a slope greater than 20 percent but less than or equal to 40 percent
    - This would indicate a change in elevation greater than 20m but less than 40 meters in a 100m run
- Terrain with a slope greater than 40 percent
    - This would indicate a change in elevation greater than 40m in 100m.

The presence of water bodies and existing passing lanes were excluded from the calculations used in this report. Water bodies were excluded to reduce complexity, as well as to reflect the fact that the 2+1 configuration can be reduced to a 1+1 design in certain high-cost locations. A bridge crossing a large river, for example, can remain two-lane even if the overall section of the road is upgraded to 2+1. Ignoring water bodies does slightly underestimate construction costs, but this effect on our estimates is offset by ignoring existing passing lanes that reduce construction costs.

The Canadian Digital Elevation Model is a geographic product created by Natural Resources Canada that gives the height of land at various points in Canada with a surface resolution of .75 arc minutes square and a vertical resolution of 1m. For the study area, .75 arc minutes square represents approximately 15m in the East-West axis and 23m in the North-South axis due to the spherical nature of the earth. DEMs are calculated from various topographic sources, and then the height of trees, buildings, and other surface objects are mathematically removed to give the theoretical height of the bare ground.

[15] Areas that were already twinned were suppressed since these areas are ineligible for a 2+1 upgrade.

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