Investments in New Road Infrastructure

Volume 1

THE PROBLEM OF URBAN CONGESTION IN CANADA

The recent CAA study *Grinding to a Halt: Evaluating Canada's Worst Bottlenecks* took a new perspective on a problem that Canadians know all too well: urban congestion is a growing strain on our economy and well-being. Canada's worst traffic bottlenecks are almost as bad as bottlenecks in Chicago, Los Angeles and New York. Bottlenecks affect Canadians in every major urban area, increasing commute times by as much as 50%.

This CAA briefing on investments in active transportation is one in a series that explore potential solutions to the problem of urban congestion in Canada. These briefings delve into solutions not only to highway congestion, but also to congestion on urban streets. Taken together the solutions explored in these briefings represent a toolkit to address this problem. The objective is to inform policy makers and the public about options to reduce congestion and key considerations for when and where a particular solution might be the right fit.

The traditional solution to congestion is to build more infrastructure. However, as cities have grown, the amount of land available for roads and highways has dwindled. Some cities have chosen to build tunnels and elevated roadways, but these solutions come with big price tags and years of planning and construction. Nonetheless, sometimes building more infrastructure is the best option. Building more does not necessarily mean totally new roads or highways; instead it could include new highway interchanges, smaller upgrades or the widening of existing roadways.

A concern is sometimes expressed that building more infrastructure will only attract more traffic. But new road infrastructure can still offer significant time savings, improved safety and reliability. As long as these benefits outweigh the costs, even if more cars end up on the road, a project can still be worthwhile undertaking.

Building smaller and lower cost projects makes more sense now than in the past. With the rapid pace of technological change, including the advent of automated and electric vehicles, predicting how much infrastructure will be required in the future has become more challenging. For this reason, big projects with long lead times are increasingly risky.

In particular, three types of infrastructure solution stand out as generally underexplored in Canada: the potential of diverging diamond interchanges, a new type of highway interchange; city-wide bottleneck removal programs; and roundabouts.

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PROBLEM: CONGESTION AT HIGHWAY INTERCHANGES

POTENTIAL SOLUTION: DIVERGING DIAMOND INTERCHANGES

How does is work & what are the benefits? The diverging diamond interchange was introduced in 2009 as an alternative to more conventional designs. The diverging diamond layout makes left turns easier and safer by having the raod crisscross while passing above, or below the highway. The layout also reduces land required compared to some conventional designs.

Examples: Missouri, Calgary, Pilot Butte overpass (Saskatchewan)

Missouri's first diverging diamond interchange reduced traffic backlogs by up to 3.2km and 46% fewer crashes were recorded in the following year. In 2017, Calgary was the first Canadian city to adopt the new design while also implementing new ways for pedestrians to navigate the unusual pedestrian path.

CONSIDERATIONS:

- **The new design may confuse pedestrians using it for the first time as the layout is different than conventional intersections.**
- **Building or replacing an interchange is a large and expensive project, so building this solution will take time to implement in a significant way.**

PROBLEM: CONGESTION IN A SPECIFIC AREA

POTENTIAL SOLUTION: LOCALIZED HIGHWAY BOTTLENECKS

How does is work & what are the benefits? Bottleneck programs target sections of highways, or busy intersections, that experience daily congestion due to inefficient road design, lane reductions, off-ramp overload, and grade changes. Eliminating bottlenecks using auxiliary lanes, ramp metering and widening ramps has the ability to significantly reduce traffic delays at a much lower cost than building new road capacity.

Examples: Minnesota, Washington and Texas Bottleneck Programs

Miesota's three most impactful projects saved driversa cumulative 1.3 million hours due to reduction in traffic delays. Washington converted a shoulder to a full-use lane for a limited distance to boost vehicle volume by 10%. Texas reduced urban congestion at 17 bottleneck points and observed a 76% decrease in vehicle collisions.

CONSIDERATIONS:

- **There are a few reasons to not at least consider a program of bottleneck reduction.**
- **Bottleneck areas can number in the hundreds in a large city so it is essential to target the most impactful to maintain a reasonable budget.**
- **Bottleneck reduction is an infrastructure solution, and so does not affect the underlying demand for roads and highways. For this reason, if economic and population growth results in more traffic that fills up the new capacity, this solution would only offer temporary congestion relief.**

PROBLEM: CONGESTION CAUSED BY LONG WAITING TIMES AT SIGNALZED INTERSECTIONS

POTENTIAL SOLUTION: ROUNDABOUTS

How does is work & what are the benefits? Roundabouts have grown in popularity across Canada due to proven results: fewer vehicle collisions and improved traffic flow. The circular nature of the roundabout slows vehicles, providing a safer encironment, while the absence of stoplights shortens idling times and benefits left-turning vehicles.

Examples: New Hampshire, New York, Washington, Kansas

Communities in the Northeastern United States experienced improved traffic flow and public acceptance after implementing roundabouts. Delays during peak traffic times were reduced by a minimum of 83%, while traffic congestion dropped by at least 58%. Building roundabouts in Kansas led to a 52% drop in the numbers of vehicles stopping at the intersection.

CONSIDERATIONS:

- **Many Canadians lack familiarity with rounabouts, so there may be some cost and effort required for driver education.**
- **Large commercial vehicles may require wider lanes to safely maneuver within the roudabout, increasing construction costs and land use for roundabouts that will handle significant truck traffic.**
- **Mini-roundabouts are used when the available land is restricted and use a centre island at street-level so that trucks can drive over**

TRADITIONAL
INFRASTRUCTURE SOLUTIONS

Dynamic city landscapes rarely afford governments the option to continuously expand highways to meet demand. Elevated highways have been used in many North American cities such as Montreal's Metropolitan Autoroute, Toronto's Gardiner Expressway and Vancouver's Georgia and Dunsmuir viaducts. This approach increases road capacity while allowing for activity (often arterial roads) to continue at ground level. However, new elevated highways have met increased resistance for a host of urban planning, social and environmental reasons such as:

- maintenance costs
- perceived lack of visual appeal
- reduced property values
- air pollution and noise

As such, governments have to be more creative in road building, in part by going underground. Seattle's new SR 99 tunnel route, a 2.7-km highway under the downtown core, will replace a viaduct. With a fall 2018 completion date, the project has been in construction for close to five years, including a two-year delay, and has an estimated cost of $4 billion.

Figure 1: Many Cities Have Gone Underground to Expand Road and Highway Infrastructure

Source: Pexels

Boston encountered similar issues with its well-known Big Dig tunnel project, a 12.5-km eight-to-ten-lane expressway under the city that replaced a six-lane elevated highway. Locals experienced a 14-year wait from project inception to completion, with a $15.4-billion overrun from initial estimates of $3.5 billion.

Upon completion, city officials saw significant reductions in traffic delays (62% reduction in travelling hours between 1995 and 2003).

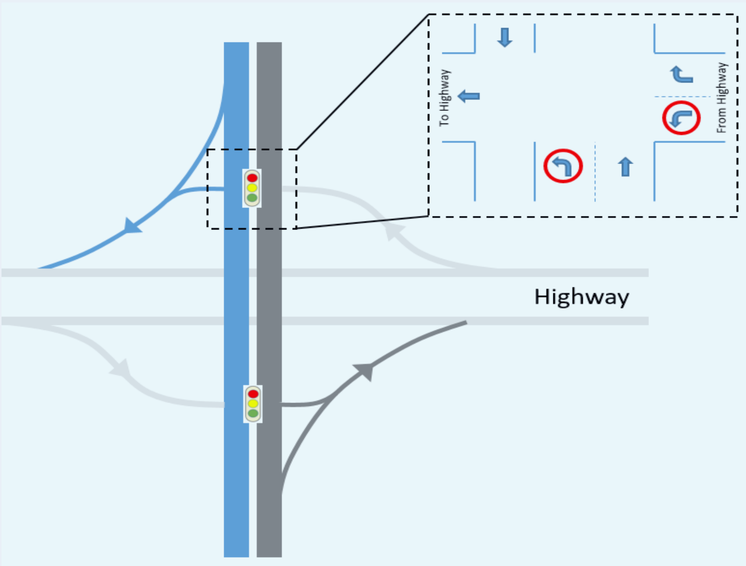
While some cities have had to go underground, there are still conventional highway building projects happening. Calgary's ring road extension will add over 40 km of six-to-eight-lane highway on the west side of the city. Under development since the 1990s, the project has an estimated construction period of five years and is expected to reach completion in 2021. The extension was given the green light to account for expected traffic growth over the next 30 years.

DIVERGING DIAMOND INTERCHANGES

A diverging diamond interchange, also known as a double crossover diamond, is a relatively new interchange layout designed to reduce traffic delays and collisions relative to a conventional diamond interchange while taking up less land than a cloverleaf interchange.

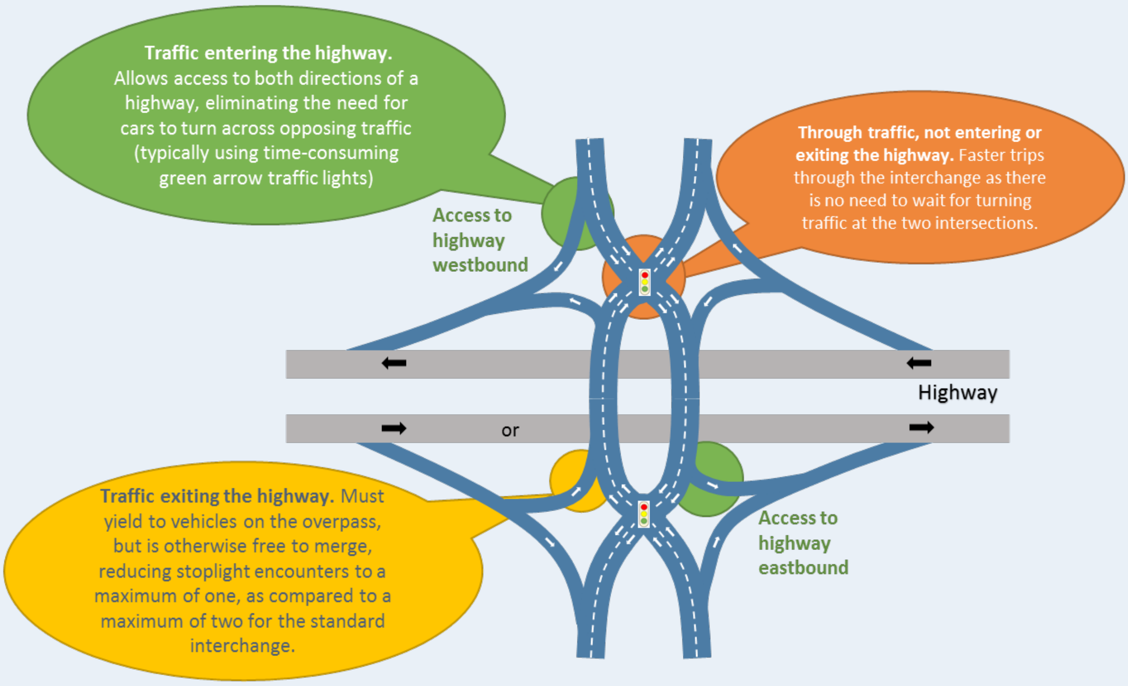
The diverging diamond interchange has three design features to reduce traffic congestion (Figure 3) relative to the conventional layout.

Figure 2: The standard Diamond Interchange



S ourrce: CPCS

Figure 3: Advantages of the Diverging Diamond Interchange



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EXAMPLES

Missouri Department of Transportation

In 2009, the City of Springfield, Missouri, became the first city in North America to implement a diverging diamond interchange. Considered a great success, the project eliminated 1.6 to 3.2 km of backed-up traffic during peak hours.

A performance evaluation conducted in 2011 found the benefits of the diverging diamond interchange to include:

- 46% total crash reduction in the first year of operation.
- Over 80% of survey respondents agreed that traffic flow conditions improved and delays decreased due to the divergent diamond interchange layout.
- 87% of survey respondents agreed that a "crash was more likely to occur" in a conventional diamond layout than in a diverging diamond interchange.

Calgary Macleod Trail & 162 Avenue

In August of 2017, the City of Calgary completed a diverging diamond interchange at the south end of the city. This area required a design that would allow quick access to the highway, but would be compact enough to fit within the available land. The interchange serves to funnel traffic from several communities and business areas, and it is therefore crucial that traffic be free-flowing on the overpass in order to prevent back-ups at intersections in close proximity. The interchange is close to Calgary's new southwest upgrades to the ring road, which should increase traffic volumes in the area. A follow-up traffic count will be conducted in the spring of 2018 to measure the fluidity of traffic through the interchange.

Pilot Butte Overpass, Saskatchewan

Currently in the planning stages, this diverging diamond interchange east of Regina will be the second in Canada.

LOCALIZED BOTTLENECK REMOVAL

Bottlenecks occur when road capacity cannot meet traffic demand, and although this may be linked to a lack of road surface area, exacerbating factors may include short acceleration lanes, permanent lane reductions and inefficient intersection design. In the worst cases, surges in demand lasting only minutes can sometimes cause disproportionately long delays. Localized issues can often be resolved with low-cost, straight-forward solutions, such as improving design. Localized bottleneck removal can be even more effective if approached as a systematic program, as some jurisdictions have done. It should be noted that bottleneck solutions address capacity issues and not demand; therefore, if demand increases, for example with population growth, the congestion relief may be temporary.

EXAMPLES

Minnesota Department of Transportation Bottleneck Reduction Process

The Minnesota Department of Transportation set out to identify and fix urban road segments experiencing short-term overload, back-ups on ramps or interchanges, and lane reductions. The Minnesota Department of Transportation identified a total of 184 bottlenecks each causing a minimum of 25,000 hours of traffic delay annually, or two hours of daily freeway delay. Of the final 19 projects selected, the Department of Transportation published results for their three most successful projects:

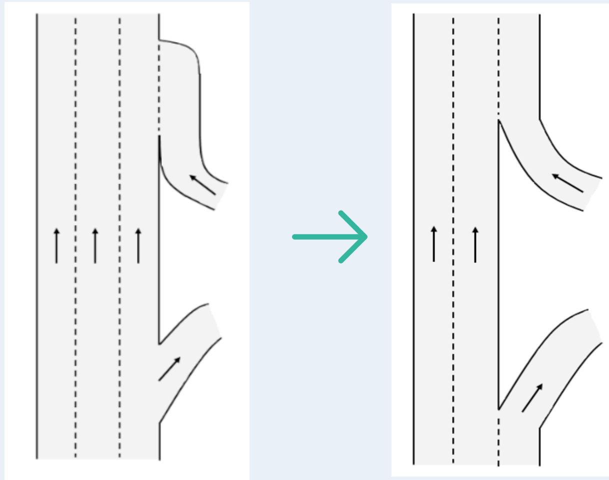
- A 1.6-km auxiliary lane addition eliminated daily 9.6-km traffic backlogs.
- Redesigning interchanges from cloverleaf to diamond designs, and utilizing sections of the shoulder resulted in reduction of queues from 8.4 km to 0.4 km.
- A four-lane section of highway was expanded to six-lanes to better accommodate the two connecting six-lane roadways, resulting in decreased congestion up to 3.2 km on each side of the highway.

In total, the three projects saved commuters an estimated 1.3 million hours annually by improving traffic flow. In comparison, Canada's worst highway bottleneck, the portion of Highway 401 north of Toronto, delays commuters by over three million hours annually. Based on CAA's 2017 study ***Grinding to a Halt***, a 1.3 million hour reduction in urban congestion in Montreal, for example, would save drivers an estimated $30 million in wasted time.

Washington Off-Ramp Lane Reduction

Washington State's Route 167 experienced daily congestion due to a temporary lane reduction between an off-ramp and downstream on-ramp. In this case, the outside highway lane became an off-ramp and a new lane was added several hundred meters later as the on-ramp lane connected to the highway (Figure 44 – left side). This temporary drop in lanes caused an upstream traffic delay before the off-ramp, and the problem was exacerbated when a local facility had a shift change after lunch. This is an example where new road capacity is not needed and instead, a practical solution would help boost capacity on this small stretch of highway. The shoulder between the off-ramp and on-ramp was converted to a full-use lane, transforming the exit-only lane to an optional exit lane (Figure 44). This low-cost solution increased the vehicle volume by 10% during peak times and significantly reduced upstream congestion.

Figure 4: Converting the shoulder to a full-use lane



Source: CPCS

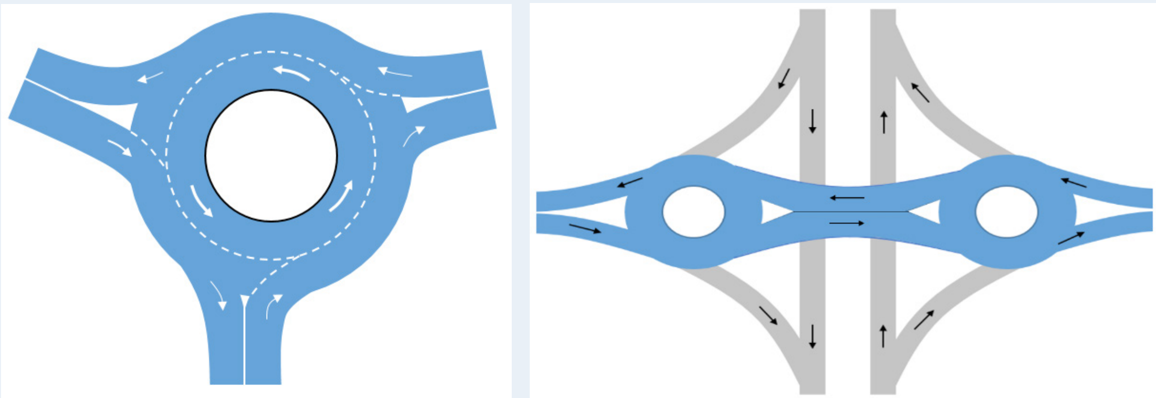
Texas Department of Transportation Bottleneck Removal Projects

The Texas Department of Transportation tackled 17 low-cost mini projects to alleviate urban congestion in areas with "no major capital improvements in the long-range plan." Tested solutions for bottlenecks were the addition of auxiliary lanes, extending lanes from a highway entrance to a subsequent exit, using highway shoulders to prolong permanent lane reductions and narrowing highway lanes to fit extra lanes. In one case, extending an auxiliary lane caused a volume boost of over 350 vehicles passing through the road segment during the morning peak hour (a 4.4% increase from pre-modification). Furthermore, a 76% reduction in collisions was observed over the following two years, which helped reduce the number of nonrecurring traffic delays. The transportation department conducted a cost-benefit analysis based on the value of lost time recovered and construction costs. It was found that benefits exceeded costs by at least three-to-one based on a 10-year project life.

ROUNDABOUTS

Relative to conventional intersection designs, roundabouts can significantly decrease collisions, annual maintenance costs, delays, travel times for left turning vehicles, and fuel consumption. Even with all their benefits, roundabouts are not an ideal solution for every intersection. They can offer the greatest benefits at intersections that have higher-than-average collisions, congestion and where light vehicles are predominant.

Figure 5: A roundabour interchange (left) and double-lane roundabout (right)



Source: CPCS

Traffic Flow Improvements

In 2004, three communities in New Hampshire, New York and Washington replaced traditional stop-sign or signalized intersections with roundabouts. Although initially public opinion favoured keeping the old layouts (only 36% supported roundabouts), the results have been positive:[9]

- Public support grew to 50% shortly after construction.
- Peak hour traffic saw an 83-93% decrease in intersection delays at all three roundabouts.
- The vehicle-to-capacity ratio, a measure of traffic congestion, dropped by 58-84%.

Operational Performance of Kansas Roundabouts

Eleven roundabouts were studied in Kansas to evaluate the operational performance of modern single- and double-lane roundabouts, compared to the previously used two- and four-way stops. The results were:[10]

- A 12.2-second reduction in average intersection delays (from 20.2 to 8.0 seconds per vehicle).
- A 52% drop in the amount of vehicles needing to stop while approaching the intersection.
- The maximum delays while approaching the intersection were limited to 10.4 seconds (previously at 34.3 seconds).

9 *Transportation Research Board (2006)*
10 Russell et al. (2004)

IMPLEMENTATION CONSIDERATIONS

As noted above, small-scale road construction projects that target highly specific congested areas have the ability to significantly reduce delays at a fraction of the cost of building new roads, tunnels or large-scale road widening.

Public perception

Public acceptance of new interchange layouts like the diverging diamond can be an uphill battle and may take time and extra promotional campaigns to convince drivers of the benefits. For example, Ohio was the first state to consider the design but dropped it due to "concerns for an unproven design."[11] In contrast, news of Missouri's first diverging diamond interchange was published in several periodicals, and ***Popular Science*** magazine claimed the design was one of the best engineering innovations of 2009.[12] Projects that successfully achieve the goal of reducing traffic delays can be used as examples to fuel more local road modification work. The high visibility of road work has the added benefit of being a self-promoting marketing campaign.

Lengthy implementation timelines

The process of implementing bottleneck solutions in an urban area can be a long one. Governments must set guidelines on what defines a bottleneck, identify bottleneck segments, narrow down the list to the most impactful projects while remaining within budget and only then begin modifying roads to improve traffic flow. The process can seem long in relation to the size of the projects. The design stage and promotional campaign leading to the decision to use a diverging diamond interchange layout in Calgary lasted approximately two years. However, lead times are short when compared to road and highway mega projects like new tunnels and elevated highways.

Projects competing for limited funds

Restricted budgets force decision makers to pick between projects. Small scale improvements can not only be spread out over a city, but also cost a fraction of a major project. Infrastructure such as tunnels and bridges can sometimes come with tolls, which may not be welcomed by the public.

11 *Chlewicki (2017)*
12 *Wootton (2009)*

TRENDS AFFECTING
COSTS AND BENEFITS

Road infrastructure projects are guided by technological developments, as described in the table below

TREND	WHAT IS IT	POTENTIAL IMPACT ON INFRASTRUCTURE
Design Simulation	With better real world data on driver behaviour and sophisticated new software, modelling the effects of new road and intersection layouts has become more accurate and reliable.	The ability to simulate traffic can be used as evidence that a road network will benefit from a new design. It also helps to convince the public, who may be resistant to new designs.

CONCLUSION

Building major new roads and highways, often elevated, in urban areas has met significant resistance. In some cities, highways have been buried as a result. Seattle and Boston dug their way to new road capacity. But sometimes there are simpler and lower cost infrastructure solutions that be implemented relatively quickly. The diverging diamond interchange has modernised highway access from overpasses by replacing left-turn lanes with crisscrossing lanes to allow free flowing traffic on to the highway. Not only does this layout prevent a backlog of cars on the overpass, it also reduces the land requirements for the interchange. A bottleneck reduction program systematically targets relatively easy-to-fix clogs in road networks by using straight-forward and low-cost solutions such as auxiliary lane additions, ramp widening and narrowing existing lanes to add an extra lane. The roundabout design has become a widely used intersection design that improves safety and traffic flow, but is not yet common in all parts of Canada.

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