TAC Technical Achievement Award – 2020
Road Safety Engineering Award

St. Peters Road Intersection: An Innovative Design Approach

INTRODUCTION

An innovative intersection design was necessary to address road safety and operational concerns at the St. Peters Road intersection on the Trans-Canada Highway in Charlottetown, PEI. The PEI Department of Transportation, Infrastructure & Energy (PEI-TIE) in association with WSP Canada, analysed numerous intersection improvement and grade separation alternatives, and concluded that a partial **Displaced-Left-Turn (DLT) intersection** configuration was the best solution.

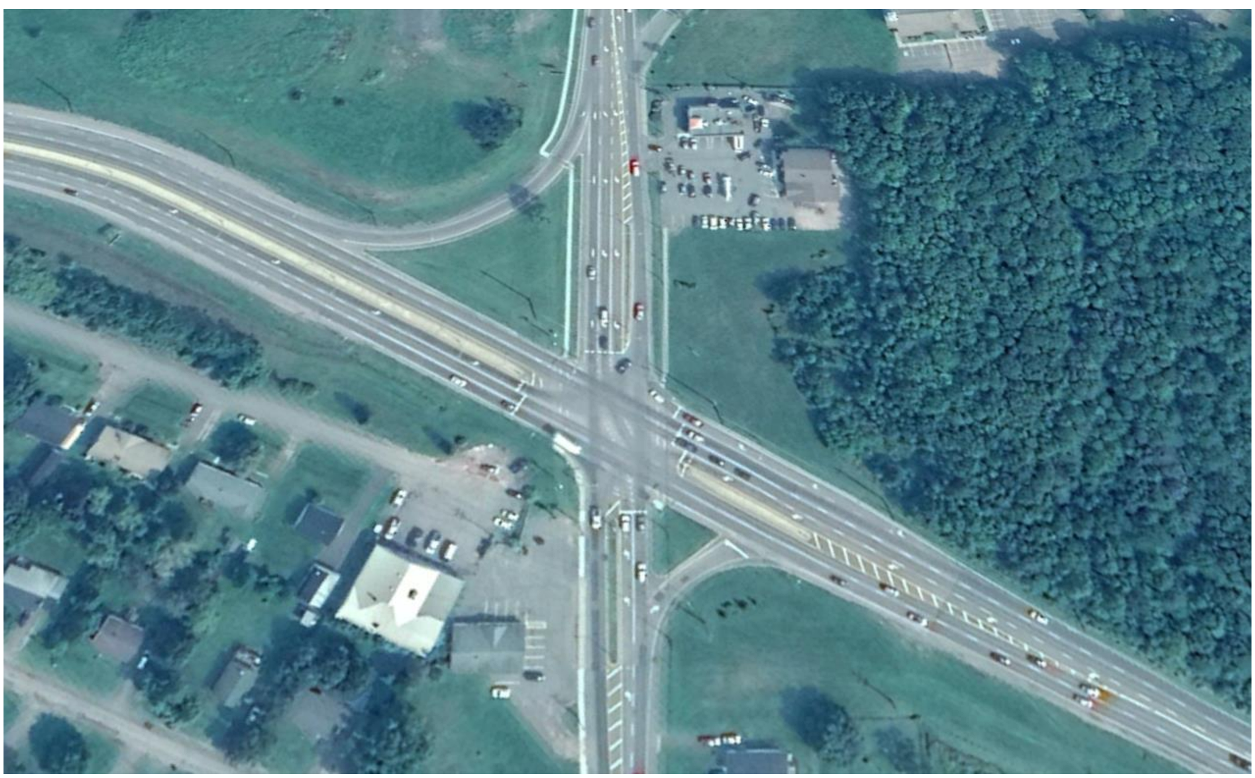
Canada's Road Safety Strategy 2025 and its Toward Zero vision of making Canada's roads the safest in the world provides an inventory of proven and promising best practices from around the world to address key road safety risk contributing factors. Although these best practices include intersection treatments such as Jug Handles, Median U-Turns, and a selection of low-cost intersection improvement options, the inventory does not include the DLT configuration. This innovative intersection alternative is promoted by the United States Federal Highway Administration (FHWA), and has been used with great success by numerous State Departments of Transportation. Although new to Canada, the DLT is recognized in the 2017 Transportation Association of Canada's Geometric Design Guide for its operational and safety benefits.

As the DLT is new to Canada, a cautious approach to analysis and design was taken. This included the application of several analytical methods and tools to assess traffic operations, and careful consideration of safety throughout the design process through the use of a senior advisory panel consisting of road safety, human factor, and innovative design experts.

This project is an excellent example of the application of new and innovative design solutions to address complex design challenges. It also provides a valuable suite of geometric design, signal, signage, and positive guidance best practices specific to the Canadian context for inclusion in future DLT intersection designs in Canada.

Figure 1: Study intersection in context within the Charlottetown transportation network

Figure 2: The St. Peters Road/Trans Canada Highway intersection

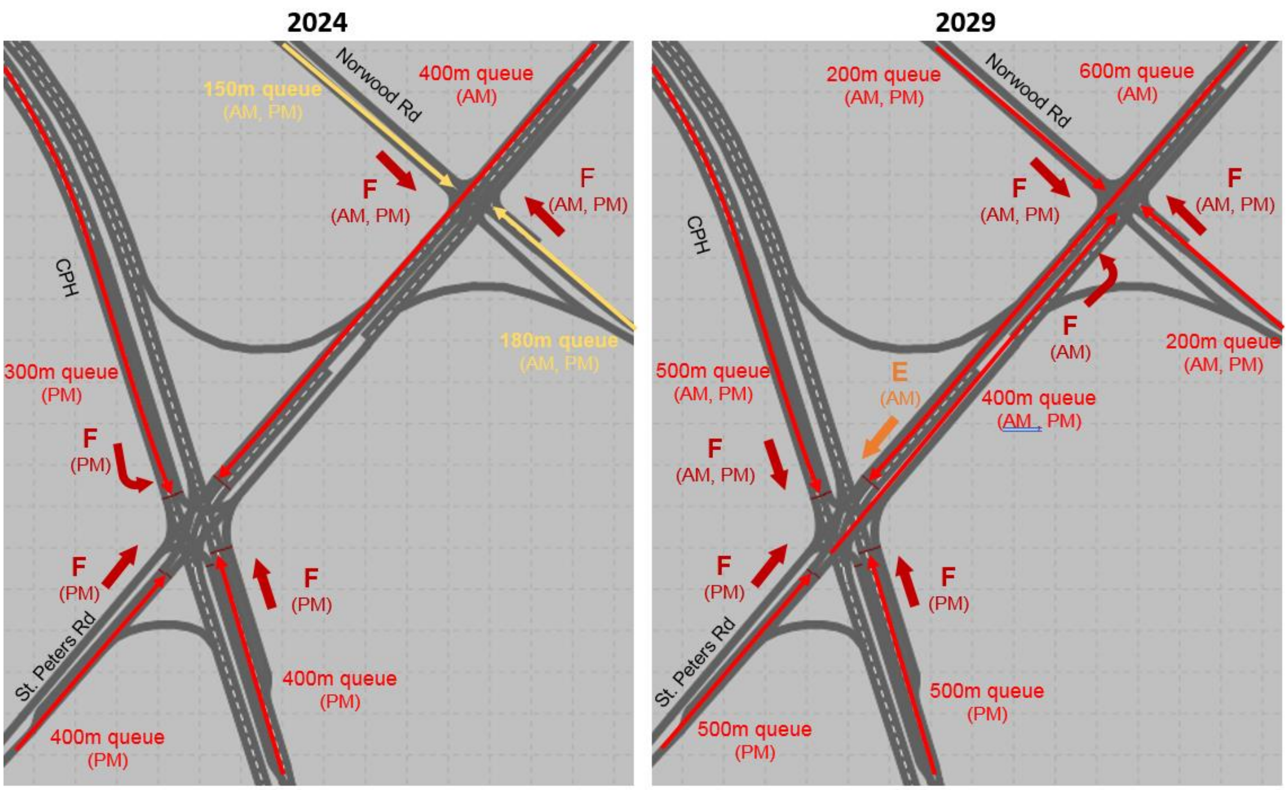


SOME BACKGROUND

Traffic operations at the St. Peters intersection have long been a concern for PEI-TIE. Heavy left-turn movements and increased development in the surrounding areas in recent years have contributed to excessive delays and long queues during both the AM and PM peak hours at this key intersection. The continued deterioration of traffic operations as traffic volumes grow is of particular concern.

An examination of traffic operations at the 2024 and 2029 horizon years suggests poor Levels of Service and excessive queue lengths on all legs of the St. Peters/TCH intersection and the upstream intersection of St. Peters Road and Norwood Road.

Figure 3: Traffic operations at the St. Peters Road/Trans Canada Highway intersection: 2024 and 2029 horizon years

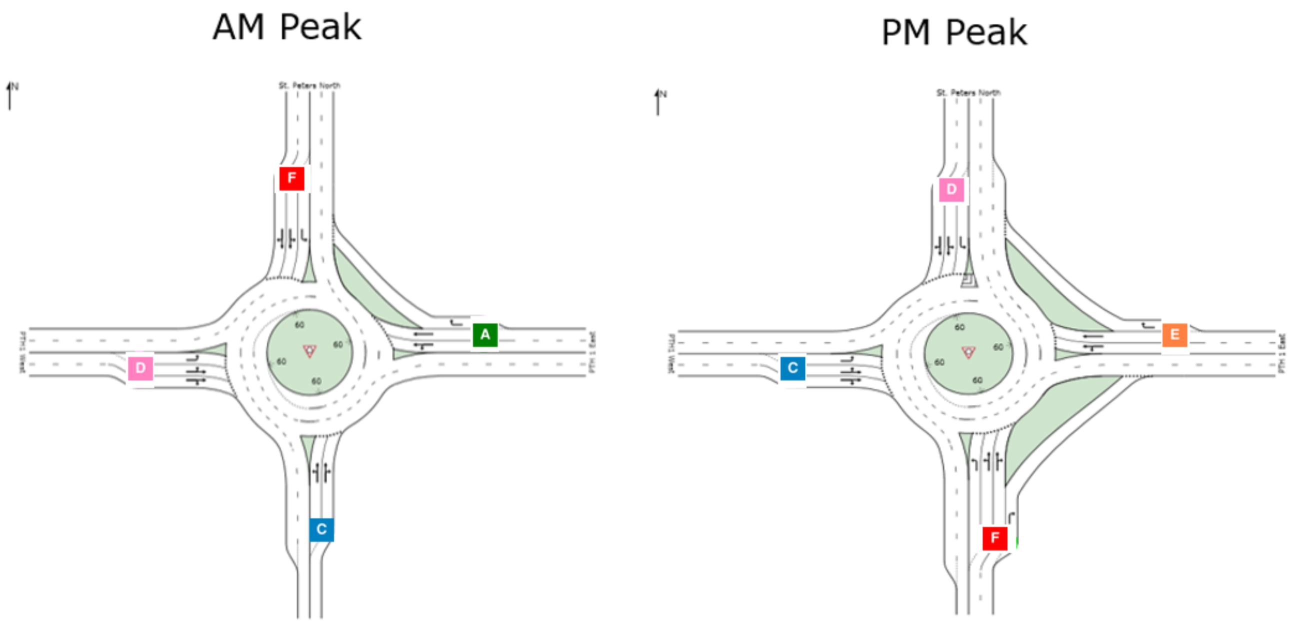


To address these concerns, PEI-TIE examined a wide range of intersection improvement options, including the following:

- **Signal optimization and additional lanes:** This option was not carried forward as these improvements had a limited life span and still resulted in a poor Level of Service and long queues at several of the key movements.

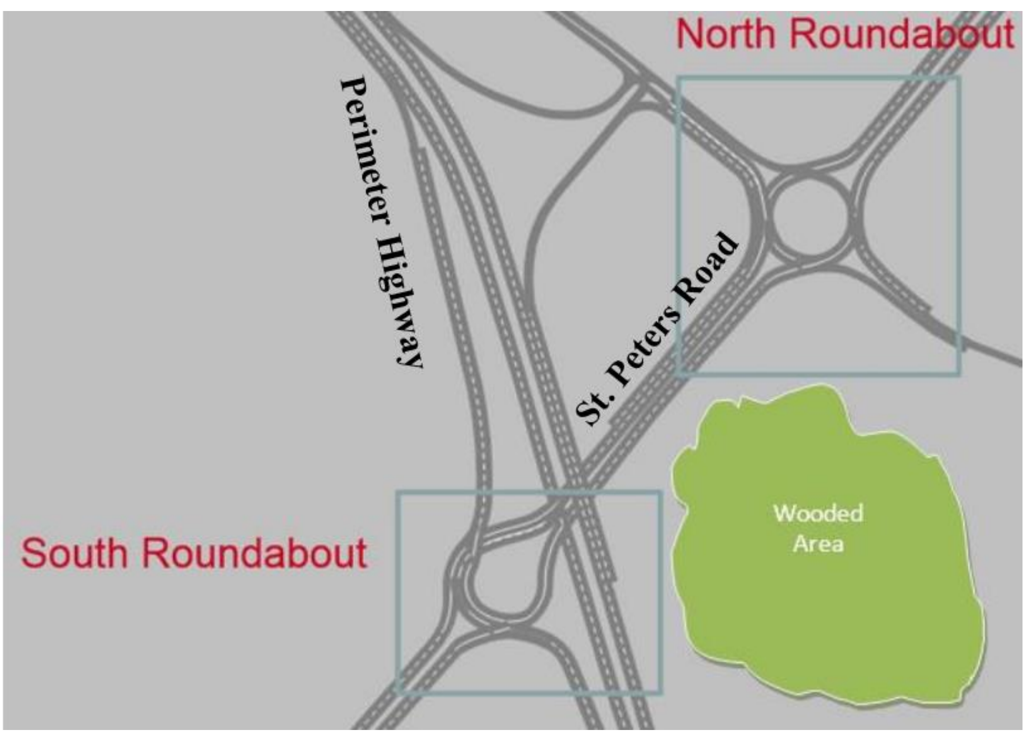
- **Roundabouts:** Several multi-lane roundabout configurations were examined. Each of these roundabout alternatives resulted in poor Levels of Service on key traffic movements during both the AM and PM peak periods. As a result, the roundabout option was not carrier forward.

Figure 4 Potential multi-lane roundabout alternatives



- **Grade separation:** Due to the constrained right-of-way, complex construction staging and traffic management, and high construction costs, this alternative was not carried forward.

Figure 5: Potential grade separation alternative



- **Reverse jug handle intersection:** Although not a common intersection treatment in Canada, the operational and safety benefits of a jug handle configuration are recognized in Canada's Road Safety Strategy 2025. However, due to the significant residential property impacts resulting from this configuration, this alternative was not carried forward.

Figure 6: Reverse jug handle intersection

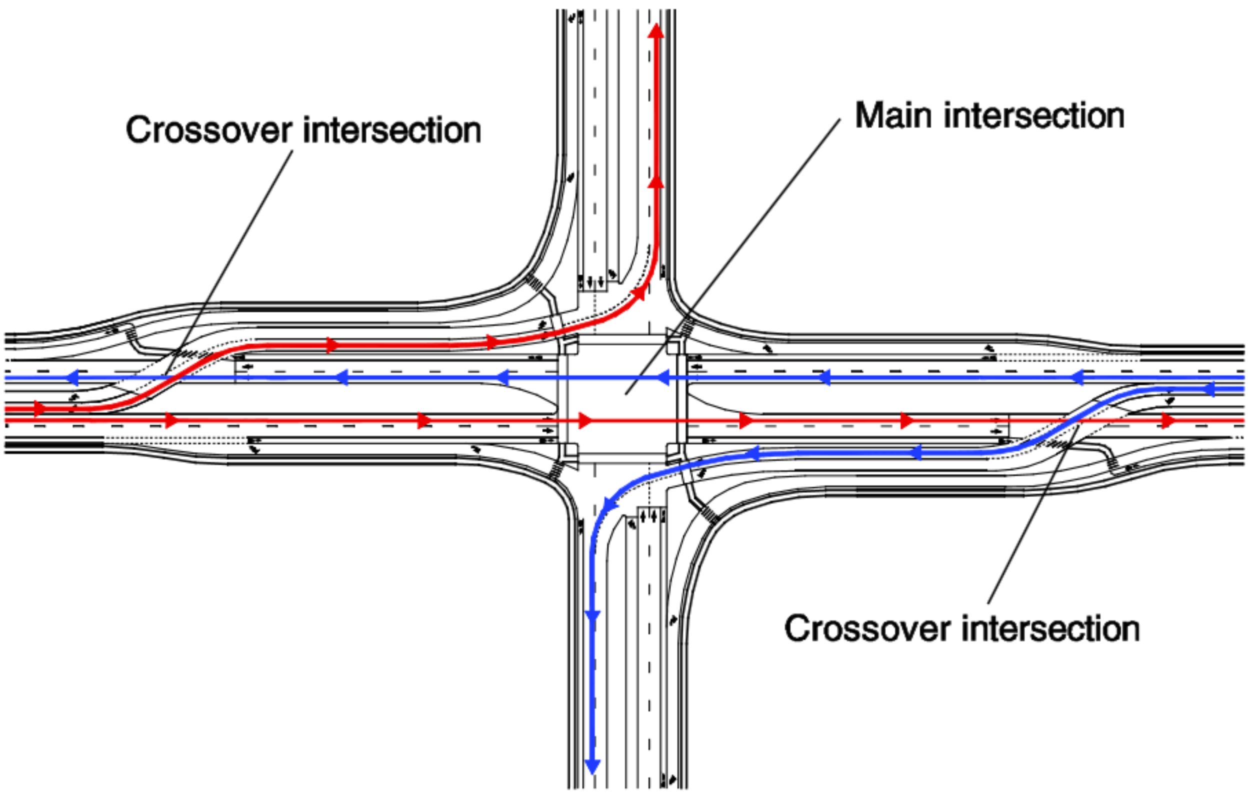
After analysing these options, the team determined that a more innovative solution was necessary to address the operational and design challenges.

AN INNOVATIVE SOLUTION

Overview

The Displaced-Left-Turn (DLT) intersection is an innovative design solution that improves safety and operations. The DLT intersection is also known as a continuous flow intersection (CFI) and a crossover displaced left-turn intersection. The term "Displaced Left" refers to the fact that left-turn movements on an approach to the intersection are relocated to the other side of the opposing traffic flow using upstream and downstream crossover intersections. This allows left-turn movements to proceed simultaneously with through movements, eliminating the left-turn phase for this approach. As a result, the number of traffic signal phases and conflict points (locations where user paths cross) are reduced at a DLT intersection, improving traffic operations and safety performance.

Figure 7: Example of a partial DLT intersection



Traffic Operations

As the DLT is new to Canada, a cautious approach to the traffic analysis was taken. This approach included the application of several analytical methods and tools to assess traffic operations. The first assessment consisted of a planning level capacity analysis conducted using the FHWA's Capacity Analysis for Planning of Junctions (Cap-X) tool. CAP-X uses the methodologies contained in the Highway Capacity Manual (HCM) 2010 to determine lane capacities to evaluate innovative intersection alternatives. CAP-X is a simple and cost-effective planning tool that helps users focus on more effective intersection and interchange designs prior to conducting more demanding traffic simulations.

Results from this analysis ranked a variety of innovative intersection design solutions based on their potential performance metrics. This analysis indicated that the DLT intersection was the best performing innovative design solution.

Figure 8: Summary of innovative intersection capacity analysis results from CAP-X

Results for Intersections														
#	TYPE OF INTERSECTION	Sheet	Zone 1 (North)		Zone 2 (South)		Zone 3 (East)		Zone 4 (West)		Zone 5 (Center)		Overall v/c Ratio	Ranking
			CLV	V/C	CLV	V/C	CLV	V/C	CLV	V/C	CLV	V/C		
1	Conventional	FULL									3186	1.99	1.99	14
2	Conventional Shared RT LN	CSRL									3466	2.17	2.17	15
3.1	Quadrant Roadway	S-W			1168	0.73			1402	0.88	1342	0.84	0.88	5
3.2		N-E	2080	1.30			1843	1.15			1244	0.78	1.30	9
3.3		S-E			1229	0.77	1229	0.77			1342	0.84	0.84	4
3.4		N-W	1501	0.94					1843	1.15	1275	0.80	1.15	8
4.1	Partial Displaced Left Turn	N-S	1272	0.79	408	0.25					1279	0.80	0.80	2
4.2		E-W					559	0.35	777	0.49	1291	0.81	0.81	3
5	Displaced Left Turn	FULL	1272	0.79	408	0.25	559	0.35	777	0.49	910	0.57	0.79	1
6.1	Restricted Crossing U-Turn	N-S	1431	0.89	1477	0.92	2321	1.45	2641	1.65			1.65	13
6.2		E-W	1362	0.85	1243	0.78	1525	0.95	1455	0.91			0.95	6
7.1	Median U-Turn	N-S	791	0.49	1217	0.76					1700	1.06	1.06	7
7.2		E-W					1500	0.94	1257	0.79	2640	1.65	1.65	12
8.1	Partial Median U-Turn	N-S	744	0.47	1082	0.68					2080	1.30	1.30	9
8.2		E-W					1447	0.90	942	0.59	2080	1.30	1.30	9

Micro-simulation was also conducted on several innovative intersection alternatives including Median U-Turn (MUT), Restricted Crossing U-Turn (RCUT) and the DLT using the VISSIM micro-simulation tool. The results from this analysis confirmed the findings from the CAP-X analysis and determined that the DLT configuration offered the greatest level of operational improvement.

Results from the micro-simulation suggest that significant improvements in Average Delay and Average Speed are realized through the implementation of the partial DLT intersection configuration.

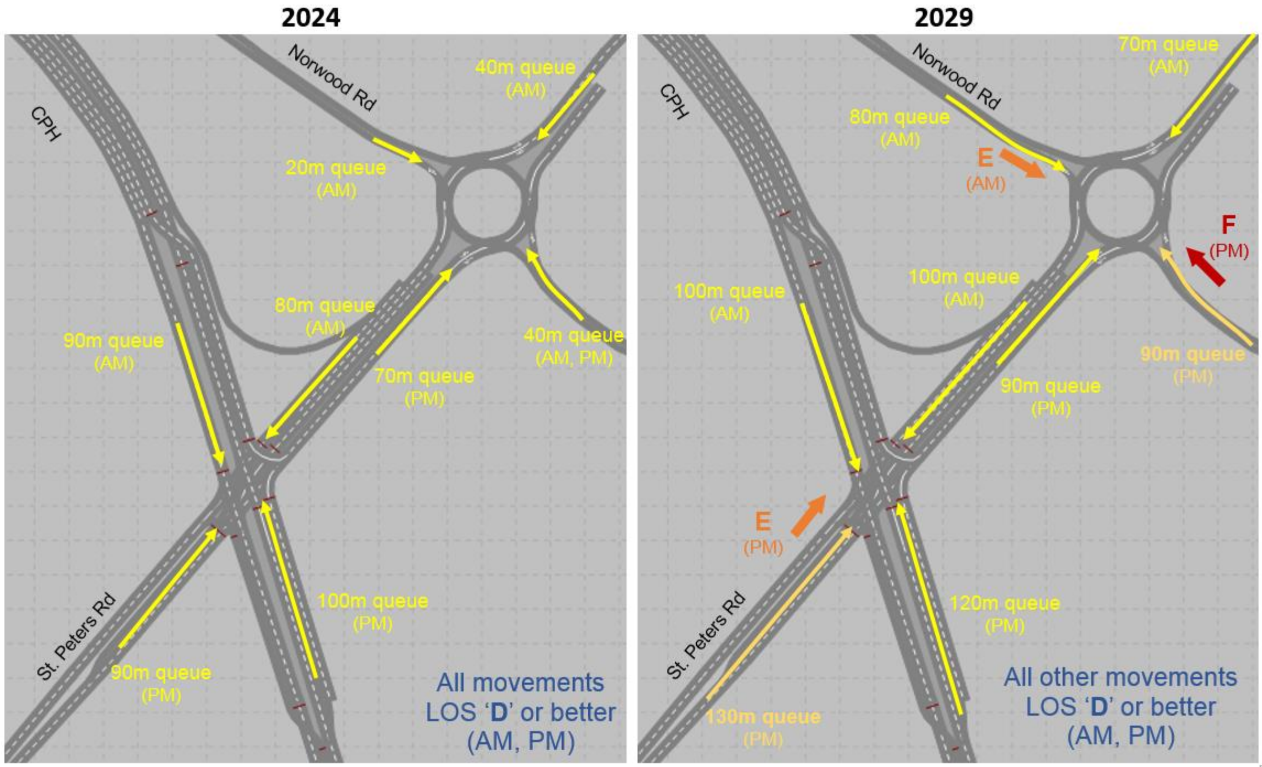
Figure 9: Comparison of Average Delay and Average Speed: Existing versus Partial DLT

CORRIDOR PERFORMANCE 2024	EXISTING CONFIGURATION		DISPLACED LEFT-TURN		BENEFITS
	AM	PM	AM	PM	
Average Delay per Vehicle	1.3 min	6.5 min	17 s	20 s	Travel time and delay within the corridor, reduced for up to 5 min per vehicle **(equivalent to > 2 traffic signal cycles)**
Average Speed per Vehicle (km/h)	38.1	21.8	43.1	42.8	Increased travel speed
CORRIDOR PERFORMANCE 2029	**EXISTING CONFIGURATION**		**DISPLACED LEFT-TURN**		**BENEFIT (averaged for AM and PM)**
	AM	**PM**	**AM**	**PM**	
Average Delay per Vehicle	*	6.7 min	19.4 s	23 s	Travel time and delay within the corridor, reduced for up to 6 min per vehicle **(equivalent to > 3 traffic signal cycles)**
Average Speed per Vehicle (km/h)	22.8	14.7	42.7	40.3	Increased travel speed

* *Inconclusive (trip not completed by all vehicles)*

A significant improvement in Level of Service and queue length was also predicted as indicated in the following figure:

Figure 10: DLT predicted LOS and queue lengths



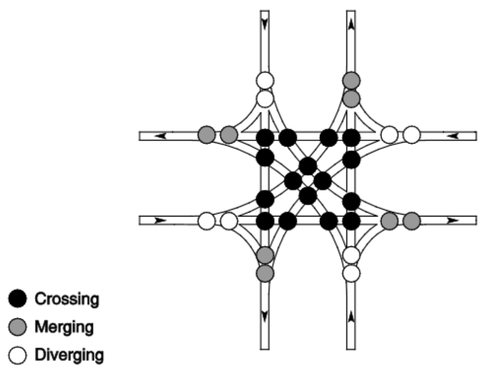
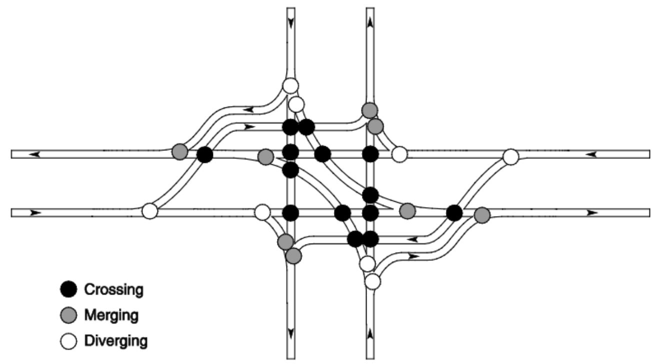
Safety

In addition to the significant traffic operational improvements that will result from implementing the DLT, safety benefits will also be realized. Compared to a conventional intersection, using the partial DLT reduces vehicle-vehicle conflict points from 32 to 30. This is a reduction of 2 left-turn crossing conflicts typically associated with increased collision severity.

Figure 11: Comparison of vehicle-vehicle conflict points

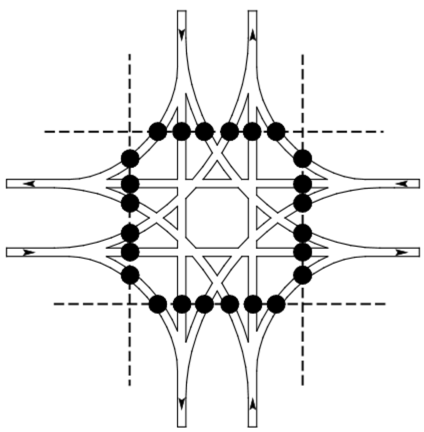
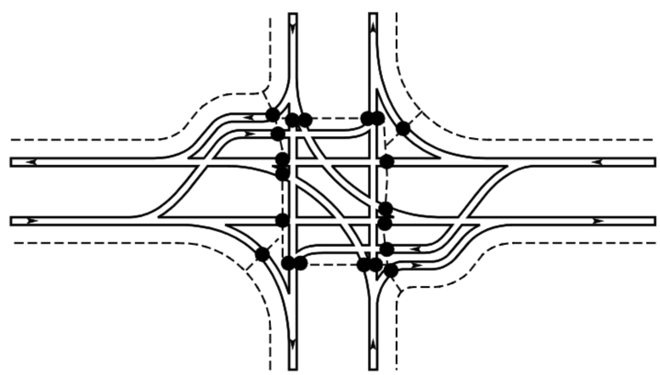
Number of Intersection Legs	Number of Crossovers on DLT	Conflict Points	
		Conventional	DLT
3	1	9	9
4	2	32	30
4	4	32	28

Figure 12: Vehicle-vehicle conflict point diagrams

Conventional Intersection	DLT with 2 displaced left-turns
	

Pedestrian-vehicle conflicts are also reduced from 24 to 20.

Figure 13: Pedestrian-vehicle conflict points

Conventional Intersection	DLT with 2 displaced left-turns
	

Although reliable CMF's for the conversion of a conventional intersection to a partial DLT configuration are not available at this time (research is ongoing), results from before-after studies in the United States suggest a 24% reduction in total crashes and a 19% reduction in fatal and injury crashes following installation of the partial DLT.

DESIGN GUIDELINES

As the DLT is new to Canada, a cautious approach to the intersection design was taken. This approach included careful consideration of safety during the design process by using a senior advisory panel consisting of road safety, human factors and innovative designer experts. Existing DLT intersection design configurations at locations throughout the United States were also observed in operation under a variety of environmental and traffic conditions to identify key road safety risk elements and design features that appeared to contribute to improved safety and operational performance. Interviews and technical discussions were also held with representatives from several State DOT's to glean information for the development of best design practices for application in the Canadian context.

These activities identified the key road safety risks and developed treatment strategies to address concerns specific to the Canadian context. The following bullets provide a list of the key road safety risks identified.

- **Potential for wrong way turning movements:** A key concern with the DLT is drivers turning right from the minor roadway into the opposing left-turn lane. To address this concern enhanced positive guidance will be offered to drivers through the provision of geometry that discourages turning into the wrong lane, signage and line painting, and signal timing and turn restrictions that reduce the risk of encountering opposing traffic in the event of a wrong way turn.

Figure 14: Avoiding right-turns into opposing left-turn lane

- **Conflicts between opposing left-turning and right-turning traffic from the major road onto the minor road:** The minor road should to have a sufficient number of receiving lanes to accommodate simultaneous left-turning and right-turning traffic from the major roadway. If this cannot be provided or there is a concern with turning lane discipline, no right-turn on red restrictions may be required. Although this can be achieved through static regulatory signage, blank out signals can also be used to enhance the positive guidance offered to drivers.

Figure 15: Opposing traffic turning left and right onto the minor roadway

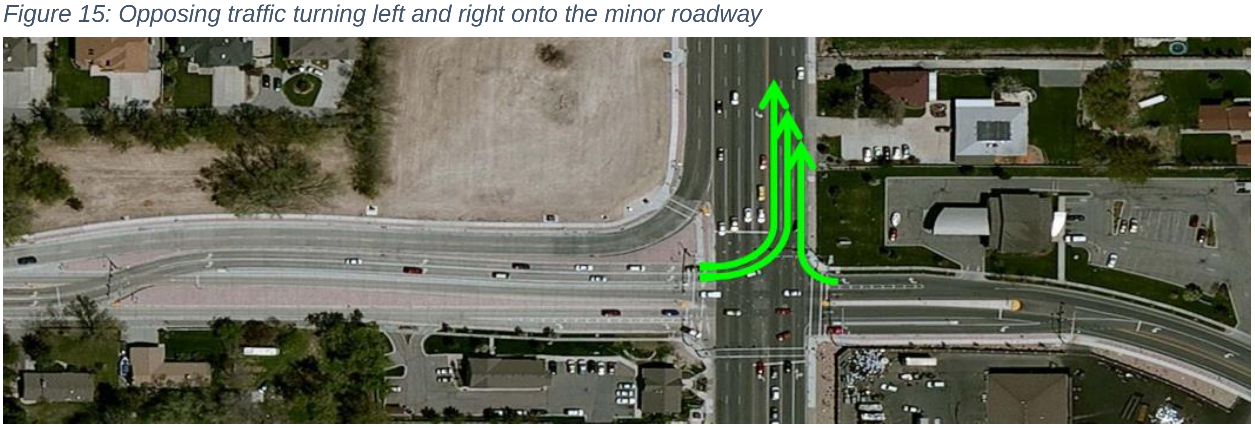
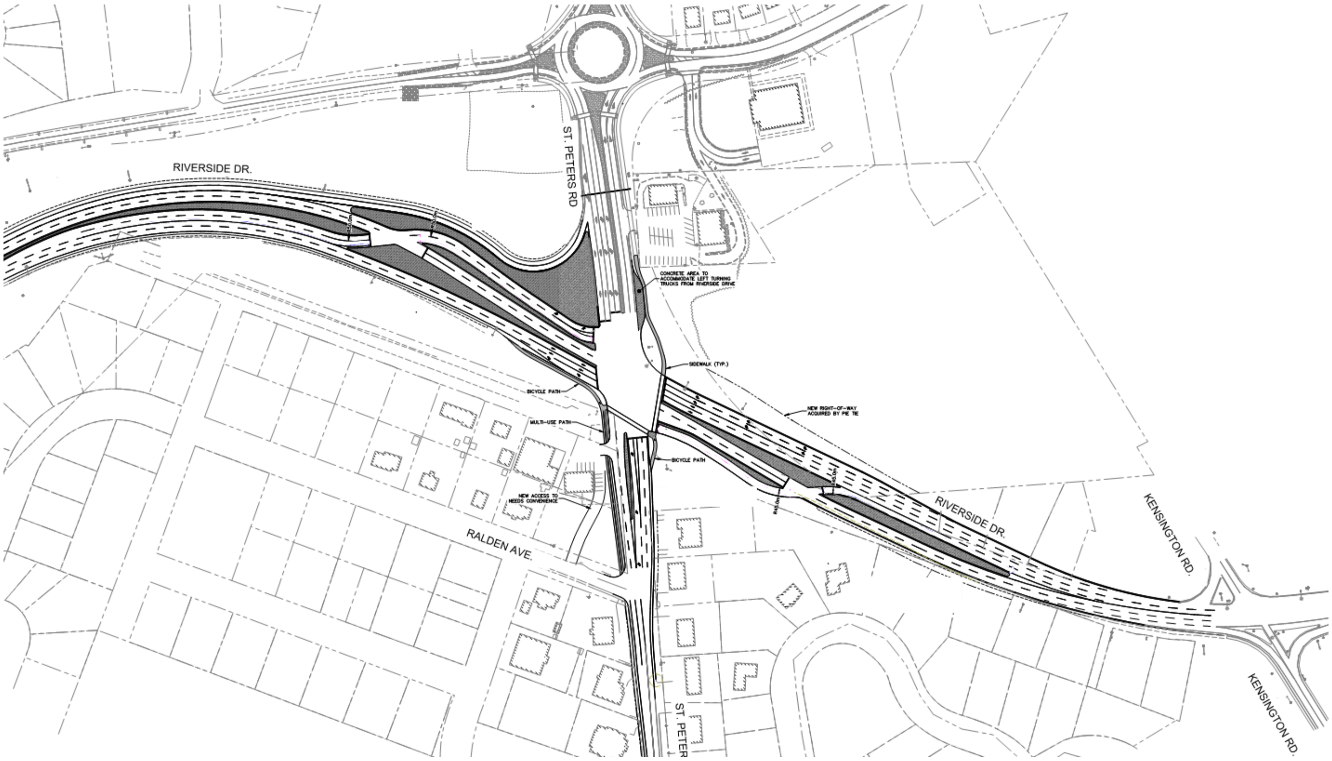


Figure 16: Right-turn blank out signal controlling right turns onto minor roadway

- **Navigation through the intersection:** The signage guidance offered in the FHWA, AASHTO MUTCD and State design manuals is limited, and in many instances the suggested guide signage appears inadequate for such a complex intersection configuration. As the DLT configuration is new to Canada and since PEI experiences a significant number of tourists during the summer who may not be familiar with this type of intersection, enhanced guide signage appeared warranted. To address this concern, human factors specialists were consulted to develop a system of guide signs that provide drivers with clear and concise guidance on the approached to the intersection.
- **Accommodation of heavy vehicle turning movements:** The accommodation of heavy vehicle turning maneuvers are of particular concern at the St. Peters intersection due to the skew angle. To address this concern, geometry at the turning and receiving lanes was carefully considered and lane designation signage for heavy vehicles was incorporated into the signage design.
- **Loss of power to signals:** The traffic operations at a DLT intersection are complex and may not be fully understood by drivers, particularly in the event of a power outage. To reduce the risk of driver error during such an event, traffic signals at the DLT intersection should be equipped with uninterrupted power supplies and provisions for the connection of a backup generator.
- **Crossover intersections:** The geometry of the upstream and downstream crossover intersections was carefully configured to consider the natural path of turning vehicles and reduce the risk of wrong-way maneuvers.
- **Accommodation of pedestrians and cyclists:** DLT intersections require pedestrian crossings that differ from conventional intersections. The position of left-turn lanes presents pedestrians with an unfamiliar crossing scenario, and the DLT intersection’s wide geometric footprint can make it challenging to accommodate pedestrians and cyclists as part of the traffic signal timing. To address these concerns pedestrians and cyclists are accommodated at the main intersection which features a single stage crossing, protected crossing phases, and countdown signals.

The following figure presents a plan view of the final DLT intersection geometry.

Figure 17: St. Peters Road intersection: Proposed DLT design



CONCLUSIONS

Innovative intersection designs can be effective at improving road safety and traffic operations. The operational analyses conducted as part of this project suggest that a significant level of operational improvement can be achieved for a fraction of the cost of grade separation. An examination of the road safety performance experienced by other US road agencies and the resulting reduction in conflicts typically associated with high collision severity also suggest that the implementation of a DLT intersection configuration will improve road safety at this location. However, as these configurations are new to Canada and may not be fully understood by users, careful consideration of the geometry and signage is necessary to reduce the risk of driver error.

This project is an excellent example of the application of innovative design solutions to address complex design challenges. It provides a valuable suite of Canadian geometric design, signal, signage, and positive guidance best practices for inclusion on future DLT intersection designs in Canada to reduce key road safety risks. The finding from this project may also help provide the information necessary to update Canada's Road Safety Strategy 2025 inventory of promising best practices to include new and innovative intersection configurations.

Construction of the St. Peters Road DLT intersection is scheduled to start in the spring of 2020.