Road Talk
Ontario's Transportation Technology Transfer Digest
Ministry of Transportation
Summer 2023

Ontario's First Diverging Diamond Interchange comes to Niagara

In 2022, the Ministry of Transportation introduced its first Diverging Diamond Interchange at Glendale Avenue and the Queen Elizabeth Way (QEW) in Niagara-on-the-Lake.


A high angle view of cars using Niagara's new Diverging Diamond Interchange.

A diverging diamond interchange (DDI) is an innovative breakthrough in road engineering. On this type of interchange, traffic on a minor street, in this case Glendale Avenue, diverges to the left-hand side of the road through two cross-over intersections. This enables left-turning traffic to access the major road or highway, in this case the QEW, without waiting for signals or crossing upcoming traffic.

DDIs improve safety and mobility for drivers by reconfiguring traffic lanes to allow for direct access to all four directional highway ramps. This means drivers will no longer have to make any left-hand turns, crossing in front of opposing traffic, when entering or exiting the highway. Instead, motorists will use interconnected crossover lanes controlled by traffic lights and signs.

DDIs can have a smaller land-use/property footprint than traditional interchanges and may be a solution when considering impact minimization for existing properties adjacent to the freeway. For example, converting an existing diamond interchange to a Diverging Diamond Interchange may provide the desired operational improvements while reducing the need for additional property.

The crossover intersections are what make DDIs different from other interchange designs. The crossovers smoothly transition traffic from the right side of the road to the left side of the road and then back again. Because traffic is on the left-hand side between the crossovers, all left turns occur without having to cross opposing traffic. The road geometry, signs, and pavement markings all work together to make this very intuitive. Reducing vehicle conflicts and allowing unrestricted left turning movements improves the overall performance of the interchange.

The study of traffic flow is a complex speciality within transportation engineering. There are several factors considered when improving traffic flow and reducing traffic congestion, including but not limited to: driver reaction times, property or infrastructure development in surrounding communities, local traffic generators and local traffic demands, weather, as well as implementation costs.

Typically, where two, two-lane roadways intersect, there are 32 possible conflict points between all vehicle paths. Diverging diamonds reduce the number of conflict points to 14. The first DDIs developed in Missouri boast a 60 per cent drop in collisions since their introduction in 2011. Calgary's DDI's demonstrate a 40 per cent reduction in overall collisions and a 75 per cent reduction in turning movement collisions.

Diverging Diamond Interchanges can be designed to be pedestrian and cyclist friendly. The Glendale Avenue DDI's multi-use path is designed to navigate pedestrians and cyclists to the interior of the traffic island, where they are protected from vehicles by concrete barriers.

Why a diverging diamond interchange?

Several years ago, the Glendale Avenue underpass was added to MTO's rehabilitation program because it was

Ontario's First Diverging Diamond Interchange comes to Niagara

nearing the end of its service life. A Preliminary Design and Environmental Assessment study, initiated in 2017, determined the preferred structure alternative and addressed factors such as:

- accommodation of pedestrians and cyclists
- incorporation of a carpool lot
- increased traffic operations near and around a newer mall and Niagara College
- protect existing forested areas

The existing underpass was replaced with a DDI, making it the first interchange of its kind in Ontario. The new interchange opened on September 26, 2022, successfully addressing key preliminary concerns.

A Brief History of DDI implementation

DDI's were introduced in the 1970's, in France, and first proposed in the United States (U.S.) by the University of Maryland in 2000. Following an intensive design study by the Federal Highway Administration (FHWA), the first DDI was completed in the United States, in Springfield, MO in 2009. Since then, over 150 DDIs have opened to traffic throughout the U.S.A., with another 80 under construction at this writing.

Ontario's DDI is only the third DDI implemented in Canada – the first was successfully implemented in Calgary, Alberta, in September 2017; then another, in Regina, Saskatchewan, in 2018.
The DDI solution was adopted in other countries around the world, including Australia, Belgium, Costa Rica, Denmark, Malaysia, Saudi Arabia, South Africa, and United Arab Emirates.

How Niagara Region benefits from this project?

By partnering with MTO, the Region of Niagara experienced a time and cost savings from the many municipal improvements that were bundled as part of the construction plan. Converting the Glendale Avenue/York Road intersection to a single lane roundabout and adding a new Airport Road ramp, and a connection road, during construction also prepares the region for continued efficient traffic movement in the future.

"Constructing the ministry and municipal improvements in a single project is more cost effective given the size of the project, and efficient, reducing the overall length of construction and the associated disruptions to traffic, compared to constructing them separately", said Joe Costantino, Area Manager, Construction, at MTO.

Aerial view of the new Diverging Diamond Interchange in Niagara.

Aerial view of a typical diamond interchange.

Aerial view of a partial-cloverleaf, or parclo, interchange on the Highway 407 Electronic Toll Route in Ontario

Aerial view of a clover leaf interchange on the Queen Elizabeth Way at Highway 27.

Ontario's First Diverging Diamond Interchange comes to Niagara

"…Improving the interchange operations increases the ease of access from the QEW to existing nearby businesses, attractions, and future developments", said John MacKinnon", Senior Project Engineer, at MTO.

Ontario's DDI project consultation and partners

The project required consultation with several stakeholders including local businesses, Niagara College, the Town of Niagara-on-the-Lake and internal MTO offices. Other provincial ministries and federal agencies were also indirectly involved to ensure the project complied with the Species at Risk Act (MNR), Ontario Water Resources Act (MECP), and Fisheries Act (DFO) legislation.

The Region of Niagara partnered with the Ontario Ministry of Transportation (MTO) by entering into a cost sharing agreement for work within the Region's authority. Construction on the DDI is part of a larger provincial construction project developing in five stages, and has several components aimed at improving overall traffic in the region.

This project was delivered using the Design Build delivery model. In a Design Build contract, the constructor also undertakes the detail design and assumes greater project risk than the more traditional Design Bid Build model. Brennan Paving and Construction teamed up with Morrison Hershfield to submit the Request for Proposal (RFP) and were awarded the contract in August 2020. Brennan Paving is the constructor while Morrison Hershfield provided engineering and environmental services including preparation of the detail design. MTO also retained AECOM to provide Construction Administration Services.

"MTO, with our Region of Niagara partners, and the contract administrators, design consultants and contractors, have done an excellent job of resolving issues brought forth by all parties. Communication and regular meetings were the key to the ongoing success of this project", said Jason Lee, Contract Services Administrator, at MTO.

"The partnership and communication with the MTO and other key team members on this project throughout all stages, has been excellent overall. With our residents and visitors as the end users, it is an exciting time in the Niagara Region to be part of this monumental and innovative form of transportation engineering" said Stephanie Huppunen, Manager, Capital Projects – Transportation Engineering, at Niagara Region.

Diverging Diamond Interchanges were cited by Popular Science as one of the best engineering innovations of 2009 and in the U.S. have been promoted as part of the Federal Highway Administration's Every Day Counts initiative.

Construction officially began in April of 2021 and completion of the contract is scheduled for Summer 2023. ●

To learn more about this project, please contact:

Joe Costantino, Area Manager, Construction | Hamilton (Transportation) at: 416-235-3613 or Joe.Costantino@ontario.ca

Jason Lee, Contract Services Administrator (Transportation) at: 905-643-9302 or Jason.Lee@ontario.ca

John MacKinnon, Senior Project Engineer (Transportation) at: 416-235-5533 or John.Mackinnon@ontario.ca

OR

Visit the contract website http://qew-glendale-interchange.ca/index.html

CHCH Sep 26, 2022, news item for Niagara's DDI: Ontario's first diverging diamond interchange opens in Niagara - YouTube

Instructional video on how to drive through a DDI, from the North Carolina Department of Transportation. Interstate 40 in this video represents the QEW in the Ontario environment: Diverging Diamond Interchange Visualization - YouTube

Road Talk online:
www.ontario.ca/fr/page/ressources-pour-les-planificateurs-des-transports

Previous issues may be found in the Ontario Ministry of Transportation Library:
https://www.library.mto.gov.on.ca/SydneyPLUS/Sydney/Portal/default.aspx

Subscribe to *Road Talk* for direct delivery to your email:
roadtalk@ontario.ca

Distributed by MTO`s Transportation Infrastructure Management Division

Road Talk
Ontario's Transportation Technology Transfer Digest
Ministry of Transportation
Summer 2023

MTO and Metrolinx awarded Tunnelling Association Canada Project of the Year for Highway 401 and 409 Rail Tunnel

In 2017, when Metrolinx wanted to tunnel under Highways 401 and 409 to expand GO train service on the Kitchener Line, they needed a Ministry of Transportation (MTO) Encroachment Permit. Central Region's Corridor Management Section brought together ministry experts to facilitate this world-class multi-year project and provided quality control / oversight for any movement of the existing tunnel and Highways 401 and 409 above.

The Metrolinx tunnelling project is featured in tunnelling magazines and praised in the geotechnical/tunnelling industry as leading-edge and award-winning. This world-class project has received industry recognition including the Canadian Council for Public-Private Partnerships (CCPPP) Silver Award for Infrastructure, and Tunnelling Association of Canada (TAC) recognized the significance of the project and awarded it Canadian Project of the Year!

MTO and Metrolinx staff are also being awarded Ontario's 2023 Amethyst Award for Service Excellence, recognizing the team collaboration when delivering the tunnel project.

With the completion of construction in July 2021, the tunnels increase capacity on the GO Kitchener Rail Corridor as part of Metrolinx's GO Expansion program. The new 180-metre twin tunnels beneath the access ramps of Highway 401 and Highway 409 enable the simultaneous passage of two trains travelling in opposite directions without speed restrictions.

Twin Tunnels under Highways 401 and 409.

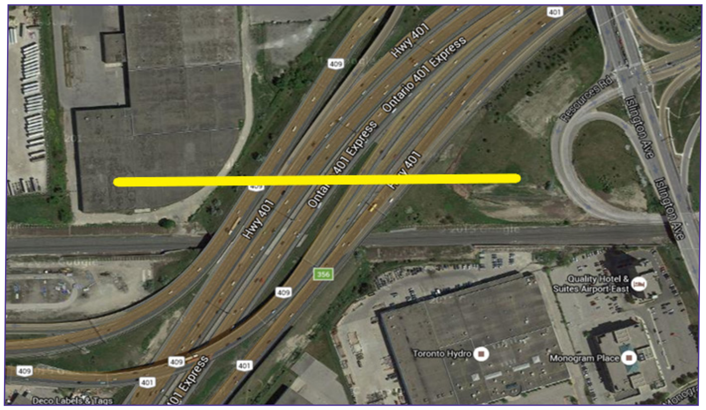
This $116.9-million design-build-finance project constructed twin,180-meter tunnels, next to an existing rail tunnel, under 21-lanes of active traffic, with only three meters of cover. The project progressed without disrupting traffic on the busiest highway corridor in North America, notably the world's busiest truck route — a significant achievement!

MTO actively collaborated with Metrolinx, by sharing information and essential knowledge to complete the tunnel. MTO played a significant role by working with Metrolinx through all phases of the project, which included: project procurement, design development, quality control, monitoring of the construction and the permitting approval process through all phases.

The project set a new standard for tunnel construction and design in Canada, by developing and employing unique construction specifications, methods, and technologies, and using a new-to-Canada auger boring system to install a pipe roof prior to tunnel excavation. This tool helped to drastically minimize risks, speed up the project schedule and protect workers. A sequential excavation method, rather than traditional cut-and-cover tunnelling, this also helped avoid traffic disruption. A complex network of monitors tracked potential displacement of the adjacent highway structures and the surrounding soil - as a safety precaution and as a measure of operational performance.

The project team developed an Emergency Response Plan to address potential issues, and they maintained regular contact with MTO Traffic and COMPASS, providing 24/7 support to

MTO and Metrolinx awarded Tunnelling Association Canada Project of the Year for Highway 401 and 409 Rail Tunnel



An aerial view of the project's location; the yellow line shows the approximate location of the twin tunnels.

Emergency Services as required. In addition to a sophisticated monitoring system, the ministry's Maintenance staff conducted visual inspections, allowing the project team to react quickly to any issues. Corridor management also provided after hours and weekend support, quality control, oversight and decision making, as required.

Expansion Benefits

GOTransit is Canada's most dynamic transit system, implementing new routes and more frequent service to meet expected demand with a growing population. It delivers opportunities to travel quickly across the region.

The Highway 401 and 409 Rail Tunnel project is a considerable first step in completing the infrastructure required to bring more GO train service to communities, businesses, and customers along core segments of the Kitchener corridor.

Kitchener, Ontario is located 108 kilometers west of the city of Toronto.

Challenging Decisions

The project team experienced unprecedented engineering challenges and significant project risks that exemplify the type of work undertaken by the MTO in supporting and improving Ontario's transportation system.

Prior to construction, Ontario faced a difficult situation - choosing from four complex options to construct a new crossing beneath Highways 401 and 409 for the Kitchener corridor, each with significant inherent risks.

MTO and Metrolinx agreed to work as a team to find an engineering solution that best addressed the requirements of both organizations to deliver a project that would support transit expansion, maintain the safety and efficiency of the provincial highway network, address the significant risks associated with the project, and ensure value for money for Ontario taxpayers.

The four options considered by MTO and Metrolinx, as well as the results of the collaborative decision-making process, are as follows:

- **Option 1** - Cancel Project - The Kitchener corridor is a provincial priority. Accordingly, this choice was eliminated.
- **Option 2** - Construct structure over highway - This option had the lowest risk management concerns, and ordinarily may have been the preferred option. However, Metrolinx advised that it would not be possible to change the alignment of the proposed rail tracks due to conflicts with existing infrastructure and the operational constraints of heavy rail. Accordingly, this choice was eliminated.
- **Option 3** - Open cut highway and construct tunnel. This option would require numerous lane closures on Highways 401 and 409, also a popular route to Toronto Pearson International Airport. Closures would have resulted in significant safety and operational impacts, to both the provincial highway network as well as the surrounding municipal road network. MTO opposed open cutting Highways 401 and 409, because the disruption would negatively affect the Gross Domestic Product (GDP) for Ontario and Canada during construction. So, this choice was also eliminated.
- **Option 4** - Tunnel under fully operational Highways 401 and 409 - Given the unique constraints of this project, MTO/Metrolinx team determined that this option was preferred and should be pursued with the clear understanding that it was unprecedented from an engineering and risk management perspective. However, several engineering challenges associated with tunneling under fully operational highways needed to be addressed.

The MTO/Metrolinx team completed an extensive evaluation of design options and construction methodologies to confirm that a tunnel was possible.

Tunneling under operational highways

A tunnel of this size designed to normal specifications would ideally be located approximately 30 metres beneath the pavement surface of the highway. In this case, the tunnel was approximately three metres beneath the surface, and the ground conditions between the top

MTO and Metrolinx awarded Tunnelling Association Canada Project of the Year for Highway 401 and 409 Rail Tunnel

of the tunnel and highways posed an excavation challenge.

The decision to continue with a tunnel at this depth required the mitigation of several significant risks, as well as an approach to tunneling that had never been undertaken in Ontario. The project is considered world-class because of the challenges it presented.

As part of the procurement process for the project, the MTO/ Metrolinx team systematically identified the major engineering challenges faced by the project, then wrote performance specifications to address and manage these concerns.

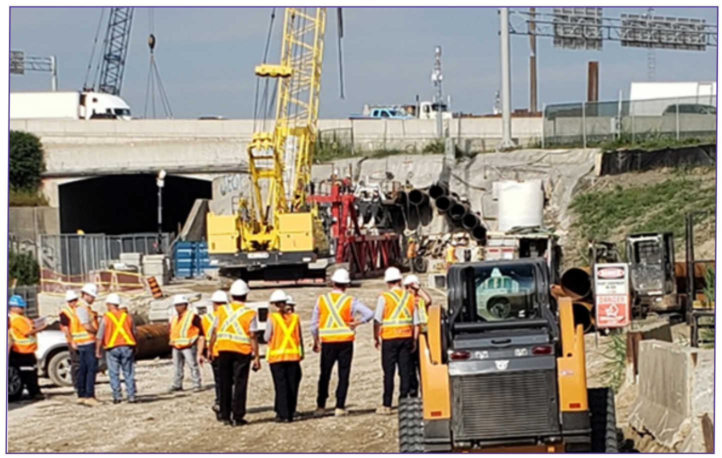
This process ensured that the selected contractor would have the necessary knowledge, experience, skills, and equipment to perform the work successfully and effectively mitigate risks.

Typically, the ministry retains engineering firms that provide technical guidance and ensure the selected contractor

Preparing for boring phase.

A view of the tunnel interior and waterproofing system.

Initial set up of excavating machinery.



MTO/Metrolinx quality control and oversight.

Twin tunnels and retaining walls nearing completion.

MTO and Metrolinx awarded Tunnelling Association Canada Project of the Year for Highway 401 and 409 Rail Tunnel

adheres to provincial standards and specifications. However, this was the first time MTO had collaborated on a project of this nature and accepted provincial standards could not fully address the proposed work. As a result, MTO and Metrolinx developed project-specific processes and procedures to mitigate the risks of this unique situation.

Engineering Solutions

Computer modelling helped in assessing the impacts of construction of the new tunnels on existing infrastructure such as highways, retaining walls, adjacent structures, sewers, luminaires, and signage.

The most sophisticated monitoring program used in Ontario, and one of the most sophisticated in North America, was used to monitor the overhead highways, as well as adjacent soil conditions.

The following unique solutions were employed for the tunnelling project:

- A comprehensive risk register was developed to identify project risks and develop proactive solutions to mitigate or minimize issues during execution of the work.
- Project-specific toolbox measures were developed to address risks during tunnel excavation.
- Specialized tunneling method was developed to address risks introduced by the limited ground cover to the highway surface.
- Specialized equipment was used for crew training and to perform work in Canada. Teams were also sent to Germany to investigate and evaluate the new tunnelling technology proposed for this project.

MTO/Metrolinx consultants and contractors worked as a single team to ensure the project met the requirements of all parties. Weekly, specialized team meetings resolved specific issues.

Team-building meetings were established to ensure all participants shared a common vision. The team implemented a dynamic and flexible work strategy to address emerging challenges during construction.

The new twin tunnels beside the existing tunnel.

World Class interior and exterior construction technique.

Engineering Results

Several innovative engineering techniques were used to meet all project technical requirements, which are considered world-class by the industry. The project was completed on schedule and - most importantly - safely, without disrupting the active highway traffic directly above the new tunnels or the adjacent railway traffic.

Conclusion

MTO and Metrolinx undertook this task because of the shared realization that the economy of Ontario is dependent on the successful integration of the provincial highway and transit system.

The team resolved many complex engineering challenges to make this project a reality. The challenges posed a significant risk but held the potential for great reward to the province. Metrolinx is delighted with the teamwork and commitment demonstrated by MTO.

MTO and Metrolinx awarded Tunnelling Association Canada Project of the Year for Highway 401 and 409 Rail Tunnel

Ultimately, both organizations consider the teamwork exhibited on this project to be a template for future collaborations.

The world-class results achieved by the MTO/Metrolinx team show the exceptional value the Ontario Public Service provides (OPS) to the Ontario public. The Highway 401 and 409 Rail Tunnel project team, including MTO Engineering, MTO Operations and Metrolinx staff, exemplified how collaborative teamwork can overcome unprecedented engineering challenges to deliver results for Ontarians. Ontario has always been a world leader in the transportation engineering field. This project is an excellent example of world-class engineering and a fantastic opportunity to remind Ontario's engineering and technical staff that their excellent contributions are important to every aspect of Ontario life and integral to the safe, efficient, and sustainable operations of the provincial transportation network.

This project provided staff in MTO/Metrolinx/OPS the opportunity to prove the engineering and technological skills of their professions and showed that all OPS staff can take part in projects of provincial significance that will challenge and develop their skills.

MTO/Metrolinx professional staff who can resolve the real-life challenges associated with critical infrastructure projects like the Highway 401 and 409 Rail Tunnel project support Ontario's goal to be "Open for Business" by delivering key innovative and technically challenging projects. ●

For more information on the Highway 401 and 409 Rail Tunnel project, please contact:

Nick Prestinaci, Head,
Operational Services,
Operations Division,
Ministry of Transportation,
at (416) 271-2223, or
nick.prestinaci@ontario.ca

Project award links:

This link features additional photos and project information:

Canadian Project of the Year Over $100M Award 2022 - GO Expansion: Highway 401 and 409 Twin SEM Tunnels | Dr. Sauer & Partners (dr-sauer.com)

Road Talk online:
www.ontario.ca/fr/page/ressources-pour-les-planificateurs-des-transports

Previous issues may be found in the Ontario Ministry of Transportation Library:
https://www.library.mto.gov.on.ca/SydneyPLUS/Sydney/Portal/default.aspx

Subscribe to *Road Talk* for direct delivery to your email:
roadtalk@ontario.ca

Distributed by MTO`s Transportation Infrastructure Management Division