Canada-United States-Ontario-Michigan
Border Transportation Partnership

Road Safety Assessment

(Conceptual Design Stage)

March 2009

Preface

The Detroit River International Crossing (DRIC) Environmental Assessment Study is being conducted by a partnership of the federal, state and provincial governments in Canada and the United States in accordance with the requirements of the Canadian Environmental Assessment Act (CEAA), the Ontario Environmental Assessment Act (OEAA), and the U.S. National Environmental Policy Act (NEPA). In 2006, the Canadian and U.S. Study Teams completed an assessment of illustrative crossing, plaza and access road alternatives. This assessment is documented in two reports: *Generation and Assessment of Illustrative Alternatives Report - Draft November 2006)* (Canadian side) and *Evaluation of Illustrative Alternatives Report (December 2006)* (U.S. side).

Practical alternatives were developed for the crossings, plazas and access routes alternatives. The evaluation of practical crossing, plaza and access road alternatives is based on the following seven factors:

- Changes to Air Quality
- Protection of Community and Neighbourhood Characteristics
- Consistency with Existing and Planned Land Use
- Protection of Cultural Resources
- Protection of the Natural Environment
- Improvements to Regional Mobility
- Cost and Constructability

This report is one of several reports that have been used in support of the evaluation of practical alternatives and the selection of the technically and environmentally preferred alternative. This report will form a part of the environmental assessment documentation for this study.

Additional documentation pertaining to the evaluation of practical alternatives is available for viewing/downloading at the study website (www.partnershipborderstudy.com).

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1. Introduction

The Border Transportation Partnership has determined that a new road link across the Detroit River in the Detroit-Windsor area is required to accommodate the growing international traffic demand. As a result of this need, the Canadian and Ontario governments have initiated an Environmental Assessment study known as the Detroit River International Crossing (DRIC) Study. The main purpose of the study is to identify a preferred crossing location for the new transportation facility.

In addition to establishing a preferred river crossing location, the Partnership has examined road access to the future crossing across Windsor and the surrounding area, and the location for the Canadian border plaza. At the current time, Highway 401 is the primary facility providing access to the Detroit-Windsor gateway from the Canadian side. However, Highway 401 terminates several kilometres from the Detroit River, and international traffic that is not destined for the Windsor area must use Huron Church Road and other “local” facilities. Improved access to the border plaza and crossing by extending Highway 401 from its current terminus to the proposed border plaza is the preferred solution in this regard.

As part of the Partnership’s requirement to determine the environmental impacts of the various access road alternatives, their commitment to road safety, and to demonstrate due diligence, the design team is seeking the opinion of a qualified road safety professional concerning the relative safety of the border plaza and access road alternatives. *Intus Road Safety Engineering Inc.* (Intus) has been retained to provide the safety assessment.

The project was initiated at the request of URS Canada Inc. on behalf of the Ministry of Transportation Ontario (MTO).

This report results from the Conceptual Design Stage Comparative Road Safety Assessment (CRSA) carried out on the conceptual designs for border plazas and access roads dated July 21, 2006, August 14, 2006, and February 13, 2008 and prepared by URS Canada Inc. for the Border Transportation Partnership.

The examiner met with Mr. Len Kozachuk of URS Canada Inc. on October 20, 2006, and discussed the design with Mr. Murray Thompson of URS Canada Inc. via telephone to be briefed on the project and to identify areas of concern.

Road safety assessments and audits have not been carried out at any previous stage of this study. However, a value engineering study of Alternatives 1, 2 and 3 was conducted on the conceptual design with specific input from a road safety engineer.

1.1 Scope

Intus has been procured to conduct a comparative road safety assessment of the conceptual design alternatives for the proposed border plaza and access road, including consideration of all road users. The level of safety analysis is commensurate with a conceptual design level of detail.

Specific concerns regarding the safety of the design alternatives are:

- The relative safety of tunnels versus open roads (both at-grade and below grade facilities);
- The movement of dangerous goods and cargo in tunnels; and
- Termination of a freeway at a border plaza.

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1.2 Objective

The objective of undertaking the CRSA is to provide input to all stakeholders on the relative safety of each conceptual design alternative so that informed decisions may be made on alternative selection. The focus of the assessment is on road safety and does not include other areas of safety that may be of concern to all those involved (e.g., slope stability, personal security from crime, etc.).

Items and design features that were not available or finalized at the time of the assessment should be checked for safety as they are made available. It is recommended that continued safety input be obtained during the future design and construction stages to ensure that safety issues continue to be explicitly addressed.

1.3 Context

In conducting a CRSA, it is acknowledged that safety is one of many considerations that roadway designers and owners need to balance in the design process, including cost, the environment, geotechnical conditions, and right-of-way availability. This review is focused on safety, with the anticipation that the findings will be used as input to decision-making, rather than as a prescription for decision-makers. The findings of this report are not directions as to what work must be carried out. The findings are intended to prompt the designers and owners to consider the safety impacts of the different alternatives, so that the impacts can be considered along with the other competing objectives of road planning and design.

It bears mentioning that as long as there are vehicles on the road, there is no "absolutely safe" highway. There are simply varying degrees of safety, and the goal of the design should be to provide a facility that is as safe as possible within the project parameters.

1.4 Format

This report documents:

- The road safety examiner;
- The method of study/analysis;
- A discussion on open roads versus tunnels;
- A discussion on dangerous goods movement in tunnels; and
- The results of the CRSA.

1.5 The Road Safety Examiner

The CRSA was conducted by Mr. Gerry Forbes of *Intus Road Safety Engineering Inc.*

1.6 Method

The CRSA has been carried out in accordance with the principles of safety conscious planning. Furthermore, the CRSA has been conducted in accordance with Evidence-based Road Safety – the application of global knowledge and research on road safety to a specific project in order to make informed decisions concerning safety impacts and concerns using the best available information.

The CRSA consisted of an office review of plans and other available material, a site visit, discussions with the designer, and a safety impact analysis using crash prediction models and crash reduction factors. Specific details of the safety impact analysis can be found in Section 2.0.

Materials provided to Intus for review are listed in Appendix A. It should be noted that the design is at a conceptual design level of detail, and the safety analysis is commensurate with this level of detail. Nonetheless, the results are suitable for a comparative analysis, since a CRSA at the conceptual design stage aims to identify and provide the relative safety performance of different design options in a quantifiable manner.

A field inspection of the study area was conducted on October 20, 2006. It is acknowledged that the site conditions during the site visit will differ substantially from those conditions in the proposed designs. Nonetheless, the existing street system, topography, and land uses provide a more complete understanding of the proposed design.

Balancing the benefits and impacts to traffic operations, safety, cost, etc. will need to be considered by the designers.

1.7 Disclaimer

The nature of prediction modeling and traffic volume forecasting is such that uncertainty is inevitable. The crash estimates provided herein are based on data provided to the examiner from others, and on the best evidence available at the time of writing. They present a coarse level estimate of safety performance and have a commensurate level of accuracy.

If all the recommendations in this report are followed, there is no guarantee that the resultant facility is "safe"; rather adoption of the recommendations should improve the level of safety of the system.

While every effort has been made to ensure the accuracy and completeness of this report, it is made available strictly on the basis that anyone relying on it does so at their own risk without any liability to ***Intus Road Safety Engineering Inc.***

2. Comparative Road Safety Assessment

2.1 Preamble

Under the current street network, long-distance traffic that is crossing the Canada-US border must use Highway 3, Huron Church Road, and the arterial street network to access the border crossings from the termination of Highway 401. This presents two safety concerns:

- The termination of a freeway at an arterial road is a “highway condition hazard” with the potential to be a serious safety concern; and
- The long-distance traffic is using arterial roads that are generally less safe than freeways and controlled-access facilities.

With respect to the former safety concern, the proposed project is not eliminating the freeway termination, rather it is relocating it closer to the border crossing and plaza. The termination of Highway 401 at the border plaza is not without it’s own safety concerns (see Section 3.1). However, the termination of a freeway at a border is a more logical and expected location for a freeway termination than at the urban periphery of Windsor/LaSalle and as such should bring about some safety benefits.

The latter concern is more substantial. It has been well-established that freeways have a lower crash risk than arterial roads, and transferring the long-distance traffic from Highway 3 and Huron Church Road to a new section of six-lane, controlled-access freeway is expected to be a significant safety benefit. Non-intersection crash data from Ontario freeways and urban arterials produce the safety performance curves shown in Exhibit 11. Depending on the volume of traffic that is being transferred from Highway 3 and Huron Church Road to the proposed Highway 401, it can be seen that there is a 30 to 60 percent reduction expected in non-intersection crashes. Therefore, any of the proposed alternatives for a six-lane controlled-access facility is substantially safer than the current condition.

2.2 Methods

At the conceptual design level of analysis, the safety performances of the access road alternatives are estimated by employing crash prediction models (CPMs) and crash reduction factors (CRFs). CPMs are essentially equations that estimate the number of crashes from one or more independent variables (e.g., traffic volume, grade, lane width, degree of curvature, etc.). In the instance of a planning level estimate, appropriate CPMs for road sections would employ traffic volume, road length, and number of basic lanes as independent variables, and CPMs for intersections would use traffic volume, traffic distribution, and number of approaches as variables. CRFs are used to modify the estimate from the CPM, if the basic geometry of the alternative being examined is different

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1 Exhibit 1 is produced from crash prediction models from *The Science of Highway Safety*, MTO (1998).

from the base condition used to develop the CPM, and the difference is expected to significantly influence crash risk.

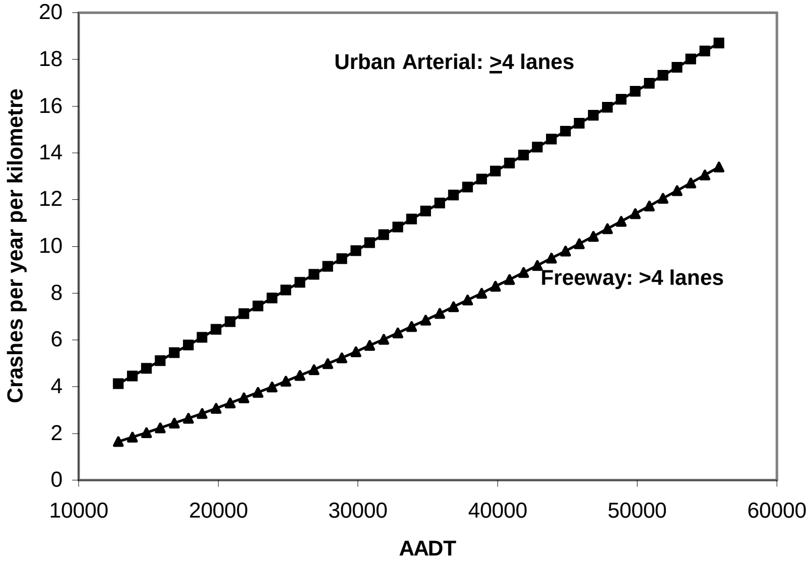

EXHIBIT 1: SAFETY PERFORMANCE CURVES FOR ONTARIO FREEWAYS AND ARTERIALS

After the models and the reduction factors have been applied, and an estimate of crash occurrence and severity has been produced, the crash risk is converted to a level of safety service (LoSS). This approach is similar to the accepted approach of using a level of service for traffic movement, and is appropriate given the coarse level of safety analysis.

The reason for using the LoSS concept is to convert the relatively precise predictions of crash risk to a more suitable qualitative scale that reflects the level of uncertainty in the analysis. Therefore, for the purposes of this comparative analysis the LoSS are determined as shown in Table 2.1.

2.3 Alternatives

The available alternatives to be assessed are shown in Table 2.2.

The alignment options for Access Road Alternatives 1A, 1B, 2A, and 2B are somewhat minor variations that for a conceptual design level of safety analysis will not yield significant differences in safety performance. Therefore, only one alignment option will be analyzed for each of the Access Road alternatives.

The safety performance will also be estimated for the access road alternatives as they connect to Plaza B only. This is because the traffic volume projections for 2035 that were made available for the analysis assumed a Plaza B connection. This should not be interpreted to mean that Plaza B is the preferred alternative.

TABLE 2.1: THE LEVEL OF SAFETY SERVICE

Level of Safety Service	Factor
A	The alternative with the lowest number of total crashes, and any alternative that has a crash total that is less than 105% of the crash total for the lowest alternative.
B	Any alternative that has a crash total that is between 105% and 110% of the crash total for the lowest alternative.
C	Any alternative that has a crash total that is between 110% and 115% of the crash total for the lowest alternative.
D	Any alternative that has a crash total that is between 115% and 120% of the crash total for the lowest alternative.
E	Any alternative that has a crash total that is between 120% and 125% of the crash total for the lowest alternative.
F	Any alternative that has a crash total that is more than 125% of the crash total for the lowest alternative.

TABLE 2.2: DETROIT RIVER INTERNATIONAL CROSSING ALTERNATIVES

Access Road Alternatives	Border Plaza	Alignment Options
1A	A, B or C	1 or 2
1B	A, B or C	1 or 2
2A	A, B or C	1 or 2
2B	A, B or C	1 or 2
3	A, B or C	N/A
The Parkway	A, B or C	N/A

2.4 The Road Network

The road network analyzed in the comparative safety assessment includes the proposed Highway 401 extension from Highway 3 to the proposed border plaza as well as Huron Church Road from Highway 3 to College Avenue, including all interchanges, signalized intersections, and the major unsignalized intersections located on the above-mentioned facilities. The safety performance of the EC Row Expressway and Ojibway Parkway sections proximate to the study area are not included in the comparative safety assessment as the geometry and traffic volumes do not vary significantly between the identified alternatives.

It is understood that the extension of Highway 401 from its current termination to the proposed border plaza may affect the geometry and traffic volumes/distribution along many of the existing local roads. These changes may have some impact on crash risk, but due to the relatively light traffic on these streets these changes in crash risk are not included in this conceptual level analysis.

The length of the mainline was scaled from the profile drawings. The length of the ramps (from bullnose to bullnose) were estimated from the plan view drawings. The length of arterial road segments along Huron Church Road were measured from Google Earth™.

2.5 Available Crash Prediction Models

CPMs are generally available for road sections and intersections; with the road section CPMs being disaggregated by the road classification and number of lanes, and the intersection CPMs being divided by number of approaches and intersection control. Ideally the CPMs used in the analysis should be developed from a crash dataset that includes roads from the network under study. For this study MTO-developed CPMs for freeway mainlines, interchange ramps, and ramp terminal intersections are available and appropriate for use. CPMs for arterial road segments, and intersections have not been developed by the City of Windsor, hence it is necessary to adopt CPMs from another jurisdiction. The Regional Municipality of Durham has a set of suitable CPMs that are employed in the analysis. The final set of CPMs used in the analysis are shown in Table 2.3.

The CPMs for the freeways and their access ramps have been developed for facilities that are open-air roadways. The safety effects of placing the freeway in a tunnel section (Alternative 3) have been studied and it has been determined that there is no change in overall crash risk by placing the freeway in a tunnel. This determination has been made using evidence-based road safety principles. Specifically, a critical review of the available research concerning the relative safety of tunneled roads versus open-air roads was conducted. Then, the amalgamated information was assessed in accordance with the specifics of the current project to develop a credible CRF. Appendix B provides a detailed discussion concerning the CRF.

In addition, because CPMs for one-way streets are unavailable at this time, the safety performance of Huron Church Road from Labelle Street to Highway 3 in Access Road Alternatives 1A and 1B, and parts of Huron Church Road in The Parkway Alternative are estimated using the following crash reduction factors for one-way street conversions:

- CRF = a one percent increase in casualty crashes
- CRF = an eight percent decrease in property damage only crashes

The above CRFs were also developed using the evidence-based road safety practice, of assessing the global research concerning the safety impacts of converting to one-way operation, and considering the collected information in the context of the current project. Appendix C provides the rationale for these CRFs.

2.6 Traffic Volumes

Traffic volumes for the year 2035 were provided to Intus by the design team for both the AM and PM peak hours of travel. Peak hour traffic is typically 10 to 15 percent of the daily traffic using a road, and as such average daily traffic for the facilities under analysis were calculated as follows:

$$ADT = DHV/0.1$$

Where: ADT = Average daily traffic

DHV = Design hour volume/peak hour

The design hour volume is assumed to be the PM peak hour. The 10 percent value was used as it produces a liberal estimate of average daily traffic.

2.7 Results

The results of the comparative safety analysis for the six access road alternatives connecting to Border Plaza B are shown in Table 2.4.

All of the access road alternatives provide acceptable LoSS for the given conditions. However, Alternative 1A and 3 provide the best LoSS.

2.8 Limitations of the Analysis

The two primary limitations of crash prediction in a planning and design study are:

- The models are only useful in a comparative analysis. Prediction models allow an analyst to understand which alternative(s) may be a safer design, but it does not allow the analyst to distinguish something that is “safe” from something that is “unsafe”.
- The current prediction models are macro-level models that account for only a few infrastructure variables that effect safety performance. While the researchers attempt to include (or at least examine) the variables that are thought to have the greatest influence on safety, this is not always the case. The specifics of each situation, as it relates to safety performance, must be reviewed by a qualified examiner. For example, the safety impact of a border plaza located near a tunnel portal is unaccounted for in the prediction models.

TABLE 2.3: CRASH PREDICTION MODELS USED IN THE ANALYSIS

Facility	Comments	Model Form	Variable			
			a	b	c	d
Highway 401 mainline *(Source: MTO, Science of Highway Safety, 1998)*	Simple freeway with 4 or more lanes in all environments (12,850 < ADT < 230,080)	$N = a\ ADT^{b}\ L$	9.41E-09 for fatal crashes 6.20E-07 for injury crashes 1.78E-06 for PDO crashes	1.4209 1.4209 1.4209	---	---
Highway 401 ramps *(Source: MTO, Operational Performance Assessment of Freeway Interchanges, Ramps and Ramp Terminals, February 2006)*	Flared on-ramps	$N = a\ ADT^{b} e^{c(length)}$	1.362E-04 for F&I crashes 6.031E-04 for PDO crashes	0.7962 0.7535	0.0968 0.9483	---
	Flared off-ramps	$N = a\ ADT^{b} e^{c(length)}$	1.064E-04 for F&I crashes 3.217E-04 for PDO crashes	0.8510 0.8911	0.3564 0.1980	---
	Loop on-ramps	$N = a\ ADT^{b} e^{c(length)}$	2.159E-04 for F&I crashes 2.383E-03 for PDO crashes	0.6741 0.5630	1.2251 1.3569	---
	Loop off-ramps	$N = a\ ADT^{b} e^{c(length)}$	2.311E-04 for F&I crashes 3.013E-04 for PDO crashes	0.7002 0.8478	1.4753 0.9718	---
Ramp terminals *(Source: MTO, Operational Performance Assessment of Freeway Interchanges, Ramps and Ramp Terminals, February 2006)*	Signalized intersection, 3-leg	$N = a\ ADT_{r}^{b}\ ADT_{x}^{c}\ e^{d(dummy)}$	2.80E-06 for F&I crashes 9.90E-06 for PDO crashes	0.6187 0.7360	0.6114 0.5351	-0.7555 -0.7636
	Signalized intersection, 4-leg	$N = a\ ADT_{r}^{b}\ ADT_{x}^{c}\ e^{d(dummy)}$	3.64E-08 for F&I crashes 5.00E-07 for PDO crashes	0.7150 0.9566	0.9685 0.6219	-2.4316 -1.3896
	Stop-controlled intersection	$N = a\ ADT_{t}^{b}\ e^{c(dummy)}$	9.502E-04 for F&I crashes 1.170E-03 for PDO crashes	0.0.5028 0.6087	-1.1066 -1.0104	---

Facility	Comments	Model Form	Variable			
			a	b	c	d
Arterial Road Segment *(Source: Region of Durham, Safety Improvement Program and Software, Final Report, November 2001)*	≥ 300 metres long	$N = a\ L^{b}\ ADT^{c}$	3.32E-04 for F&I crashes 1.205E-03 for PDO crashes	1.000	0.838	---
	< 300 metres long	$N = a\ L^{b}\ ADT^{c}$	2.28E-04 for F&I crashes 9.29E-04 for PDO crashes	0.688	0.860	---
Intersections *(Source: Region of Durham, Safety Improvement Program and Software, Final Report, November 2001)*	Signalized, 3-leg	$N = a\ (ADT_{m} + ADT_{s})^{b}\ (ADT_{s}/(ADT_{m} + ADT_{s}))^{c}$	7.40E-02 for F&I crashes 1.81E-01 for PDO crashes	0.304	0.157	---
	Signalized, 4-leg	$N = a\ ADT_{m}^{b}\ ADT_{s}^{c}$	1.26E-06 for F&I crashes 3.13E-06 for PDO crashes	1.111	0.373	---
	Unsignalized, 3-leg	$N = a\ ADT_{m}^{b}\ ADT_{s}^{c}$	2.31E-06 for F&I crashes 5.39E-06 for PDO crashes	1.021	0.219	---
	Unsignalized, 4-leg	$N = a\ (ADT_{m} + ADT_{s})^{b}\ (ADT_{s}/(ADT_{m} + ADT_{s}))^{c}$	2.93E-03 for F&I crashes 6.03E-03 for PDO crashes	0.676	0.450	---

N = Number of crashes per year
L = length of segment (km)
ADT = Average Daily Traffic (vpd)
Dummy = 1 if ramp terminal has a channelized right-turn, 0 otherwise

TABLE 2.4: RESULTS OF THE COMPARATIVE ROAD SAFETY ASSESSMENT

Alternative	Annual Crashes in 2035			LoSS
	F&I	PDO	Total	
1A - At-grade facility with one-way service roads	59	171	230	A
1B - Below grade facility with one-way service roads	71	202	272	D
2A - At grade facility along side Huron Church Road	67	196	263	C
2B - Below grade facility along side Huron Church Road	67	196	263	C
3 - Tunneled facility under Huron Church Road	62	180	242	B
The Parkway Alternative	64	184	247	B

Other limitations include:

- The analysis conducted herein estimates the safety performance for the horizon year 2035 only. The safety performance of each alternative will change as traffic volumes and road geometry changes in the ensuing years.
- Traffic volume projections often produce imbalances between adjacent intersections/interchanges. This analyst did not attempt to reconcile the imbalance in traffic volumes between adjacent nodes.

3. The Border Plaza

Border plazas are a special condition in highway design, for which Canadian standards and guidelines have not been developed. Therefore, the starting point for plaza design must be the applicable geometric highway design guidelines for common public roads, and the human factors principles on which they are based. At the present time there are no quantitative measures for assessing difference in safety between border plazas. All options appear to provide an acceptable level of safety. However, there are significant differences between the plaza options that will impact on safety.

3.1 Common Safety Issues to All Options

The primary safety concern associated with all of the border plaza options is that the access road has been designed as a high-speed, 400-series freeway that terminates at the border plaza. The border plaza requires vehicles to reduce speed and stop and has the potential to cause queuing at times when traffic volumes exceed customs processing capacity. This being the case, a border plaza situated at the end of a high-speed facility creates a longitudinal speed differential that will increase crash risk. Since a border plaza is a required element of the design the method of mitigating this speed differential is to treat the access road to:

- Slow approach speeds by introducing physical elements that are known to achieve this result; and
- Structure the drivers' expectations concerning downstream traffic and physical conditions through advance warning/signing.

With respect to slowing approach speeds, the streaming of information/objects in peripheral vision or "optical flow" is the biggest influence on sense of speed. Therefore, introducing peripheral stimuli will increase the sense of speed and cause motorists to slow down. On an open road this is traditionally done using landscaping (e.g., trees), signing, and pavement markings (i.e., at the eastern end of Highway 407). The use of a tunnel on the approach to the border plaza may be an effective means on managing approach speeds as research has demonstrated that tunnels cause a reduction in driving speed [Amundsen (1992), Bampfylde et al (1978), Chiyoda (1995), Theeuwes et al (1995), and Gallagher et al (1979)]. The speed reduction can be made more effective if a non-regular texture is used on the tunnel wall [Kaptein et al (1996)][2]. A below grade freeway section would be expected to have a similar effect on driving speed as the tunnel, as the closed environment and roadside retaining walls would provide a similar peripheral stimuli.

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[2] The location of the border plaza relative to the tunnel portal is an important safety consideration. The crash risk in tunnels is highest near the portals therefore it is not advisable to place the border plaza too close to the tunnel portal. However, the distance between the portal and the plaza should not be so great as to allow motorists to increase speed. There must be an appropriate separation between the tunnel portal and the border plaza for this treatment to remain effective in mitigating crash risk.

In addition to increased optical flow, it is well established that drivers tend to slow down as the driving task becomes more demanding. For example, narrowing the lane width, is a method of increasing the complexity of the driving task to affect slower speeds. However, narrow lanes are also associated with increased crash risk, therefore they must be used judiciously – for example, wider shoulders might be used in connection with the narrower lanes.

In terms of structuring driver expectations of the downstream plaza (and/or traffic queues) there are two measures available. Firstly, the elements of the facility should be transitioned from freeway standards to urban road standards on the approach to the border plaza. For example, high mast lighting may be transitioned to traditional urban street lighting. By presenting the visual scene as an urban road rather than a freeway, then the motorist expectation will be structured to select a slower speed. Secondly, adequate placement of warning and information signs using positive guidance principles is required. Given that the border crossing has the potential to create queues of varying lengths and durations, active warning through variable message signs is considered essential.

3.2 Lessons Learned from Toll Plazas

Border crossings are, in many ways, similar to toll plazas that require motorists to slow or stop on a high-speed facility to pay a highway toll. A yet to be released American study [Rephelo (2008)] examined the safety concerns of toll plazas and the strategies to combat these concerns and will report the following safety findings:

- Plazas present unique challenges in terms of lane-changing behaviour and merging:
    - Motorists often making last-minute lane changes to find the shortest line;
    - Ramps immediately upstream or downstream of a plaza may cause weaving;
    - The length of acceleration lanes and lane drops are often constrained; and
    - Complications may arise due to truck traffic and over-size loads.

- Strategies that may be employed to combat unsafe lane changes and merging are
    - Install physical barriers or a buffer lane to separate lanes with different speed profiles;
    - Use delineators to channelized traffic upstream of the plaza;
    - Make the delineators more visible by using wide yellow hazard markers instead of small white delineators, and by positioning the delineators in a “bowling pin” configuration instead of in a straight line;

  - Channelize traffic downstream of the plaza to prevent early merging;
  - When there are ramps proximate to the plaza, use physical barriers to prevent vehicles in entry/exit lanes from making unsafe manoeuvres across multiple lanes in a short distance;
  - Consult truck drivers and trucking associations concerning the most appropriate locations and configurations for truck traffic;

- High approach speeds may be addressed through:
  - Marking the speed limits or advisory speeds on the pavement surface on the approaches;
  - Using transverse lines or rumble strips on the approach pavement to create an increase in optical flow;
  - Use real-time speed feedback signs for each lane;
  - Increase enforcement at plazas including using automated speed enforcement at plazas;
  - Double fines for speeding in the vicinity of plazas; and
  - Implement a public outreach campaign targeting speeders.

- Strategies to minimize driver confusion and provide positive guidance are:
  - Provide suitable advance warning concerning which lanes are closed at the plaza;
  - Use pavement markings to designate different use lanes (if required);
  - Employ signs that convey messages in the least confusing manner (i.e., simple signs); and
  - Use white strobe lighting at plazas to highlight facilities during inclement weather (particularly during foggy conditions).

The above strategies may be considered moving forward. The above discussion concerns traffic safety at the border plaza and does not discuss worker safety.

3.3 Qualitative Comparison of Options

All four of the border plaza options (A, B, B1, and C) appear to provide an acceptable level of safety. However, preferences between the options from a safety perspective are established through application of the following principles:

- The border plaza places a significant cognitive load on the driver, and there should be an adequate separation between the information-handling zone for the border plaza and the adjacent upstream “hazard”.
- Forward visibility of the roadway and traffic should afford the driver time to detect, perceive, and react to the downstream situations.

- The approach to the plaza should be aligned so as to assist in slowing approach speed to the plaza.

With the above principles in mind:

- Although Plaza A provides good forward visibility, and horizontal curves to affect slower speeds, it is not preferable as it is located proximate to the interchange ramps with the EC Row Expressway.
- Plaza B and B1 have similar concerns regarding the proximity of the border plaza to the interchange ramps with the EC Row Expressway/Ojibway Parkway.
- Plaza C is the preferred option from a safety perspective, as it provides the greatest separation between the plaza and the adjacent interchange, and it introduces a large radius curve that provides a good balance between speed reduction and forward visibility.

3.4 Conclusions

All of the border plaza options appear to provide an acceptable level of safety. However, Plaza C is the preferred option from a safety perspective because it provides the greatest separation between the plaza and the adjacent interchange, and it introduces a large radius curve that provides a good balance between speed reduction and forward visibility. In all options, the primary safety concern is the longitudinal speed differential created by a high-speed, 400-series freeway terminating at the border plaza. Measures should be introduced to slow approach speeds to the border plaza, and to structure the expectations of drivers concerning the downstream road and traffic conditions.

Treatment of a freeway termination is a significant safety concern, and regardless of which plaza option is selected for detailed design, continued safety input should be sought on this issue. Given the significance of the facility, driving simulator studies are recommended as early in the design process as practical.

4. Other Safety Issues

4.1 Interchanges

From a safety perspective one of the main determinants of crash risk on a freeway, or restricted-access facility is the number and configuration of accesses (i.e., interchanges). Crash risk on freeways is highest in the vicinity of the interchange speed change lanes, where merging and diverging create turbulence in the traffic stream. Therefore, safety is enhanced on the mainline by limiting the number of entrances and exits. This is in contrast to the need for accessibility, which encourages appropriately placed access points to connect to the surrounding street network.

In all of the alternatives under consideration it is a safety improvement if the number of points of access to and from the access road is minimized. Since the access road connection to the border plaza supports the project goal of providing for the safe, efficient and secure movement of people and goods across the Canada – U.S. border, the number and placement of interchanges will depend on the origin and destination of cross-border traffic.

4.2 Huron Church Road

In Alternative 2A Huron Church Road becomes discontinuous at Spring Garden Road. In other words, traffic traveling on Huron Church Road and passing Spring Garden Road must perform a right (for northbound traffic) or left (for southbound traffic) turn in order to continue traveling on Huron Church Road. This type of route discontinuity is a minor safety issue. Associated with the route discontinuity is the “see through” problem associated with the HCR realignment. The old road allowance must be visually obscured from approaching traffic so that motorists are not provided with the visual information that HCR continues straight at this location.

4.3 The Parkway

The Parkway has two safety issues that bear mentioning:

- There is a ramp from the EC Row Expressway to Highway 401 that crosses the Ojibway Parkway immediately upstream of the intersection of the Ojibway Parkway with the EC Row Expressway. The overpass structure has the potential to limit the visibility of the traffic signal heads controlling the intersection of Ojibway Parkway at the EC Row Expressway, and should be considered in further design stages.
- The Parkway shows a fairly extensive off-street pedestrian-bicycle network that will yield significant safety benefits to these vulnerable road users.

5. Dangerous Goods Movement Through Tunnels

Since one of the access road alternatives includes a tunnel of significant length, it is important to address the issue of dangerous goods movement in tunnels.

5.1 Terminology

Many products pose some danger while being transported, but dangerous goods are generally products that are inherently dangerous even when they are not in transport. These materials, substances, and organisms include explosives, gases, flammable and combustible liquids, flammable solids, oxidizing substances, poisonous/toxic and infectious materials, radioactive material, corrosives, and other products deemed to be dangerous to life, health, property or the environment when transported.

Dangerous goods, hazardous material, and hazardous goods are synonyms. In Canada, the term dangerous goods (DGs) is typically used, and will be used throughout this report.

5.2 Safety Concerns of Dangerous Goods in Tunnels

The consequences of crashes involving DGs can be more serious in tunnels due to the confined space of the structure – although this is not always the case. For example, a corrosive substance spill is not likely to be any more serious if it occurs in a tunnel as opposed to open air. The incidents that are of most concern when considered in the context of a tunnel are; explosions, large-scale releases of toxic gas, and violent fires. In all of the above incidents, the cause is not necessarily a motor vehicle crash. In fact, research demonstrates that the majority of DGs incidents are related to packaging, and load securement. Regardless of the cause of a DGs incident, because the resulting consequences can be more serious than in open air, it is necessary to consider DGs movement within a tunnel.

5.3 Canadian Regulations

International and inter-provincial/inter-territorial movement of DGs is governed by the Transportation of Dangerous Goods Act, 1992 (TDG Act). The primary purpose of the TDG Act is to ensure the safety of everyone affected by the movement of DGs and the preservation of the Canadian environment.

In Canada, the federal government and each of the provinces and territories have enacted legislation to regulate the transportation of dangerous goods. While the jurisdictional coverage of these pieces of legislation varies, the intent is consistent and, to that end, each piece of legislation adopts the Transportation of Dangerous Goods Regulations made under the federal statute. The TDG Act applies only to international and interprovincial movement of goods, therefore parallel provincial and territorial regulations are available to control road transport within individual provinces and territories.

The TDG Act is structured to address issues such as containment, labelling, enforcement, penalties, emergency response plans, etc. It does not provide any guidance concerning the routing of dangerous goods, or the suitability of different facilities and infrastructure for accommodating dangerous goods.

Legislation is available in each province and territory to regulate the movement of DGs on specific roads and routes. The Transportation Association of Canada's Manual of Uniform Traffic Control Devices, and the provincial/territorial equivalents, include road signs for permissive and prohibited DGs routes. The experience concerning DGs movement is fairly limited in all Canadian jurisdictions except Alberta. The regular and routine movement of petroleum products by road through and around Albertan communities has caused the province and many of the municipalities to develop criteria for establishing DGs routes. With respect to tunnels in particular, British Columbia has enacted legislation that expressly prohibits the movement of DGs through tunnels except when a Ministerial permit has been issued.

5.4 Experience from Elsewhere

The Organization for Economic Development and Cooperation (OECD) in conjunction with PIARC (the World Road Association) investigated the movement of DGs through road tunnels, including determining current national and international regulations. Twenty-one countries (including Canada and the United States) participated in the OECD survey. The survey revealed that while rules and regulations regarding DGs movement through road tunnels varied considerably within and among countries, most countries (including Canada) have no general rules or regulations concerning DGs movement in road tunnels. However, regulations are frequently enacted and enforced for specific tunnels including under water crossings, urban locations, and older infrastructure.

The OECD/PIARC survey revealed that, in general the strictness of the regulations increases as the number of road tunnels in the jurisdiction decreases. No explanation is offered for this finding.

United States

The movement of DGs in the United States is first and foremost controlled by the Code of Federal Regulations, Title 49 (Transportation), Part III (Federal Motor Carrier Safety Administration of the Department of Transportation). The relevant excerpts concerning DGs movement in or near tunnels are as follows:

- Part 397.67(b) – Motor Carrier Responsibility for Routing, which states "A motor carrier carrying hazardous materials… shall operate the vehicle over routes which do not go through or near heavily populated areas, places where crowds are assembled, tunnels, narrow streets, or alleys". Exceptions are permitted where: there "is no practicable alternative" route; or the deviation is required for emergency conditions, or to reach destinations, or facilities for fuel, rest, and repairs. Operating convenience is not considered to be a factor in determining the practicability of a route.

- Part 397.69 – Highway Routing Designations, which essentially provides states and Indian Tribes, and political subdivisions of the state with the ability to designate DGs routes, and routes where DGs are prohibited. The designation of routes must comply with Federal standards.

The designation of DGs routes and routes where DGs are prohibited by state and local road authorities is to be determined by employing the most recent version of the Guidelines for Applying Criteria to Designate Routes for Transporting Hazardous Materials [FHWA, 1996] or an equivalent routing analysis which adequately considers overall risk to the public. The general risk factors to be considered include: population density, type of highway, level of service/congestion and crash experience of the facility, emergency response capabilities, amount and type of DGs, terrain, continuity of routes, alternative routes, effect on commerce, and exposure/other risk factors. Public and stakeholder consultation are also essential elements of the analysis.

The US guidelines make special mention of bridges and tunnels as locations where DGs are normally prohibited because they are typically located on “critical service routes”, and maintaining regional mobility is often an explicit goal of the roadway agency. However, the guidelines also state that an assessment of DGs movement through a tunnel should be subject to a relative risk analysis with alternate routes. If permitting DGs through the tunnel presents a substantially lower risk than the alternatives, the road authorities may want to reconsider any general prohibition of DGs in the tunnel.

A 1975 survey of American roadway authorities concluded that “[v]ehicles carrying hazardous materials are prohibited or severely restricted at most tunnels”, although a few tunnels “have no posted restrictions on hazardous cargoes” [TRB, 1975]. The restrictions on DGs in tunnels are generally posted on the approach to the tunnel, and are usually self-enforced (see Exhibit 5.1). In select instances, personnel at tunnel entrances conduct intermittent or continuous inspections of DGs vehicles. Nonetheless, carriers are expected to know and obey the rules and regulations.

Europe

In the years 1999 to 2001 several highly publicized crashes involving DGs movement through road tunnels have launched a surge in research and reviews of tunnel safety. Europe is a tunnel-rich continent and the bulk of the experience in tunnel safety and the movement of DGs through road tunnels has originated from the European Union. Each country is free to set regulations as they see fit and a great variety of restrictions are imposed on the transport of DGs in road tunnels, including: complete prohibition, minimum inter-vehicle distances, maximum speed limits, hourly/daily limitations, escorting requirements, mandatory notification of cargo, limitations on the amount and type of substances, requirements in terms of vehicle and tunnel provisions, etc.

EXHIBIT 5.1: EXAMPLE OF A DANGEROUS GOODS PROHIBITION SIGN

The Commission of European Communities seeks to establish cross-jurisdictional guidelines that will harmonize regulations and ease the international movement of DGs. To that end, the Europeans recommend that the decision to permit/prohibit DGs movements through tunnels should be established through a quantitative risk assessment (QRA) of the practical routes, including the tunnel route. The QRA is a data-intensive analysis that quantifies the relative risk to human health of transporting DGs on different routes. It is a scientifically sound method that can assist decision-making. The QRA model has been developed by a group of subject matter experts on DGs movement and relative risk analysis.

5.5 Conclusion

The Canadian experience with DGs movements through tunnels is limited. Generally, there are no restrictions on the transport of DGs through Canadian tunnels. The main exceptions being the Detroit-Windsor Tunnel which prohibits all DGs, and some urban area tunnels in British Columbia and Quebec where only small quantities of DGs are permitted.

The existence of an alternate, open-air route is not sufficient grounds to prohibit DGs movements through a tunnel. Such a decision considers only the consequences of a DGs incident. Risk is comprised of consequence, exposure, and probability of occurrence, and the prudent practitioner will consider exposure along the alternative routes, and probability of a DGs release (e.g., the number of crash-causing situations along the routes).

Prohibiting DGs movement through tunnels is a trade-off. What is gained in safety in the tunnel is, at least partially, shifted to other parts of the transportation network. The ultimate decision on whether DGs should be prohibited in the tunnel (including the time periods of prohibition, and/or which DGs are prohibited) should be determined by a QRA. It is acknowledged that current decisions on whether a tunnel should have restrictions on the transport of DGs, are in most countries not based on detailed QRAs. However, this is clearly becoming the “industry standard”.

The Ministry’s current policy concerning the movement of DGs is that all provincial facilities, being the backbone of the surface transportation network, will be DGs routes. Therefore, from a policy perspective a QRA is not required. The policy is supported by two important factors:

- Alternative routes would also have to traverse populated areas of Windsor and the surrounding territory, so there is no significant gain from reducing exposure; and
- Freeways are statistically safer facilities than arterial and collector roads, so placing DGs on the freeway will reduce the probability of a motor-vehicle crash causing a DGs spill.

In the end, a complete QRA is not warranted based on provincial policy and because there is no significant indications to suggest that an alternative route may be substantially less risky for the movement of DGs.

Nonetheless, if the tunnel option is selected, and DGs movements are permitted, the Ministry may wish to consider regulating quantities of specific DGs in the tunnel, and/or curfews or time limits on DGs movements. Other interventions that are available and may be considered are:

- Requirement for escort vehicles;
- Written advance notification to the tunnel operators;
- In-vehicle warnings (i.e., warning lights and strobes) in addition to the DGs placards; and
- Mandatory pre-tunnel entry inspections.

The preceding discussion considers only the risk of an incident involving DGs movement and does not consider other important criteria that will affect decision-making on DGs movement in a tunnel. The most evident are:

- Risk perception and aversion: The public perceptions of DGs movement.
- Economic impacts associated with a decision: Includes impacts on carriers from having to use potentially longer alternate routes, and the impact of losing a critical link in the surface transportation network for a significant period of time, if an incident should occur in the tunnel.
- Route vulnerability: Impacts on the natural and social environments including watercourses, historic buildings, etc.

6. Tunnel Design

The tunnel option (Alternative 3) provides a comparable level of safety service to the open road options. While the consequence of a crash in a tunnel is greatly increased over those on an open road, catastrophic events are fairly infrequent. If the tunnel option is to move forward then the designers should be mindful of the following safety recommendations.

It should be noted that both Alternative 3 and the Parkway Alternative are options that contain tunnels; if tunnels are defined as underground passages of indeterminate length that are completely enclosed except for an opening at each end. However, there is a distinct difference in the tunnels of Alternative 3 and those of the Parkway Alternative in that the Parkway Alternative employs a series of short tunnels, which do not require ventilation systems, and do not require escape routes, cross-connections, or lay-bys. In this regard it is more appropriate to describe the underground passages of the Parkway Alternative as “covered highways”.

The safety principles and design recommendations contained in this section are directly applicable to the tunnel in Alternative 3. Some of these principles and recommendations are generally applicable to the longer covered highways in the Parkway Alternative. For example, the light transition at the portals is applicable to a long covered highway as well as a tunnel. However, tunnel length information to structure driver expectations is not applicable to the covered highway. The designers must assess the applicability of each of the following recommendations in light of the conditions and parameters of each covered highway in the Parkway Alternative.

6.1 Tunnel Safety Principles

The primary objective in tunnel safety is incident prevention; the secondary objective is incident mitigation (i.e., enabling tunnel users to self-rescue and to mitigate damages, efficient action by emergency services, protecting the environment, and limiting material/infrastructure damage). Project safety can be maximized by considering the following safety chain:

- Prevent hazardous conditions and situations (proactive);
- If the hazard cannot be eliminated, decrease the likelihood of an incident and limit the potential consequences (preventative);
- Should an incident occur, provide optimal chances of escape (corrective);
- Have well-prepared emergency services (repressive); and
- Restore the situation to pre-incident conditions (follow-up).

A well-developed safety philosophy will address all areas of the safety chain, but will inculcate interventions as “high up” the chain as possible to prevent the incident.

The myriad of factors that affect tunnel safety can be grouped under four general categories: infrastructure, operations, vehicles, and road users. By managing safety in all four categories, the level of safety in a tunnel is maximized. It is evident then, that the safety of tunnels is determined by more than just the physical condition and configuration of the infrastructure. Administrative authority, planning for repairs, incident management, transport of DGs, driver education, and tunnel regulations are all important determinants of overall tunnel safety. Detailed discussion of these factors, except infrastructure, is beyond the scope required at this stage of planning.

6.2 Design Recommendations

Should the tunnel alternative move forward, infrastructure recommendations for a tunnel such as that accommodating Highway 401 through Windsor are:

- A twin-tube tunnel with unidirectional traffic should be used given the forecasted traffic volumes.
- If it is not possible to drive out of the tunnel because of congestion, transverse and/or semi-transverse ventilation shall be used.
- Cross-connections for self-rescue shall be at intervals of less than 500 metres, depending on traffic.
- Cross-connections shall be designed for pedestrians, but every third cross-connection shall be designed for the passage of emergency service vehicles.
- Appropriate means shall prevent the propagation of smoke or gases from one tube to the other.
- Immediately in front of the tunnel portal, a median crossing shall be provided to allow emergency services to gain immediate access to either tube.
- The distance between lay-bys shall not exceed 1000 metres or the distance prescribed by a risk analysis conducted by the road authority (This is not necessary if the full shoulder width is maintained through the tunnel).
- Grades shall not exceed five percent.
- The height of the tunnel ceiling affects the rate of fire growth; low ceilings increase heat.
- Longitudinal ventilation promotes the spread of fire longitudinally in the tunnel.
- Traffic control devices (other than pavement markings) should be used sparingly within 200 metres upstream of the tunnel portal. Road users tend to fixate on the dark/light tunnel portal in this area, and are likely to miss the information being conveyed by the device.
- Similarly, tunnel users will focus their attention on adjusting speed and path after first entering the tunnel. Therefore, traffic control devices within the first 200 metres downstream of the tunnel portal should not convey important information.
- To minimize the light transition at the tunnel portal, increase the luminance level in the tunnel near the portal (e.g., use a bright colour for the tunnel walls, and increase illumination), and decrease the luminance level upstream of the tunnel (e.g., using a dark road surface, and planting trees or other tall elements).

- Employ video monitoring and automatic incident detection systems.

Traffic control devices required upstream of the entrance portal should convey the following messages:

- Permitted height of vehicles (if applicable);
- Prohibition and regulations concerning DGs;
- Tunnel length information to structure driver expectation;
- Destination information (i.e., border plaza); and
- Alternative route information.

Given the proposed cross-section of the facility, the expected high volume of commercial vehicles, and the potential for border queuing, information signs should be placed overhead to maximize conspicuity. Consideration should be given to erecting other traffic signs on both sides of the road for this same reason.

Also with respect to traffic control devices – In crisis situations (i.e., a tunnel fire) human behaviour is such that the common reaction is initially disbelief, and an underestimation of the actual risk present. Furthermore, experimental studies have demonstrated that evacuating persons require five to 15 minutes to determine whether to react, and decide on the appropriate reaction. Deviations from the normal pattern of behaviour are difficult to illicit, and therefore in crisis situations information presented to the driver on variable message signs and alike, must be unambiguous, and understandable.

The above recommendations are largely derived from and consistent with those proposed for road tunnels by the Organisation for Economic Cooperation and Development, and the World Road Association (PIARC).

6.3 Design Considerations

Further human factors principles that the design team should consider in tunnel design are:

- Avoid using red and yellow colours on the tunnel interior as they may create an illusion of fire in the tunnel;
- Reduce or mitigate sudden large black unlit gaps (e.g., ventilation tunnels, off axis turn arounds, etc.) as they can be disturbing to drivers causing them to swerve or suddenly slow down;
- Continuous light tubes on both sides of the tunnel wall create a feeling of width and increase driving comfort.

6.4 Driving Simulator Study

There are at least three areas of safety concern that have been identified with the tunnel option that would require further study, likely in the form of driving simulator tests. They are:

- In-tunnel Accesses: Tunnels around the world have traditionally been constructed to traverse obstacles, and are linear facilities without intersecting roads and ramps, although this is not always the case. The provision of on-ramps and off-ramps in a tunnel is a rare enough situation that driver reactions to these situations are largely unknown. Driving simulator studies indicate that well-designed and well-spaced ramps should not introduce any undue hazard to tunnel users. This should be confirmed for the specifics of this project through driver simulator testing.
- Information Signing: In a similar vein, both on-ramps and off-ramps require signing on the mainline. In a tunnel, the limited space makes placement of appropriately-sized traffic signs challenging, and a factor that must be considered early in the planning and design stage. The driving simulator tests would assist in making appropriate in-tunnel signing decisions.
- Border Plaza: A unique challenge that is presented by the tunnel option that is not covered in the literature is the border plaza that would be located near the western portal. The research indicates that the crash risk near the portals of the tunnel (i.e., within about 200 metres) is higher than elsewhere within the tunnel, and the placement of the border plaza in this vicinity will exacerbate the situation. That is not to say that the safety impact caused by a border plaza being vicinal to the tunnel portal cannot be mitigated. A multidisciplinary and detailed examination of border plaza safety, including human factors considerations, during subsequent stages of the tunnel planning and design would be required.

6.5 Further Safety Input

At the current time, there are no TAC or AASHTO standards or guidelines specifically for highway tunnels [FHWA, 2006]. Therefore, application of the current standards for geometric design, and freeway maintenance and operations are the logical starting point for continued development of the access road design. It is recommended that the design team continue to seek safety input on subsequent stages of the design, up to and including the pre-opening stage. The form of input should be commensurate with the stage of design, and the issues at hand, and may include road safety audits, specific comparative road safety assessments between alternatives, and driving simulator studies.

7. Summary

Under the current street network, long-distance traffic that is crossing the Canada-US border must use Highway 3, Huron Church Road and the arterial street network to access the border crossings from the termination of Highway 401. It has been well-established that freeways have a lower crash risk than arterial roads, and transferring the long-distance traffic from Highway 3 and Huron Church Road to a new section of six-lane, controlled-access freeway is expected to be a significant safety benefit.

The results from a conceptual design stage CRSA of the six access road alternatives connecting to Border Plaza B[3] are shown in Table 7.1, and indicate that all of the access road alternatives provide acceptable LoSS for the given conditions. However, Alternative 1A provides the best LoSS. The Parkway Alternative and Alternative 3, the tunnel, have the second best LoSS at "B".

TABLE 7.1: RESULTS OF THE COMPARATIVE ROAD SAFETY ASSESSMENT

Alternative	Annual Crashes in 2035			LoSS
	F&I	PDO	Total	
1A - At-grade facility with one-way service roads	59	171	230	A
1B - Below grade facility with one-way service roads	71	202	272	D
2A - At grade facility along side Huron Church Road	67	196	263	C
2B - Below grade facility along side Huron Church Road	67	196	263	C
3 - Tunneled facility under Huron Church Road	62	180	242	B
The Parkway Alternative	64	184	247	B

The following is the proper interpretation of Table 7.1:

- All of the proposed alternatives provide an acceptable level of safety.
- The levels of safety for each alternative *are preliminary design level estimates*, based on cursory design *information that is available* at this stage of the planning and design process.
- The principle difference in the level of safety afforded by the various alternatives arises from the different arrangements and configurations of the supporting street system and not from the location of the mainline (i.e., at-grade, below grade, or tunnel).
- Alternative 3 and the Parkway Alternative have the same LoSS and are within five crashes of each other. At a preliminary design stage analysis, for all intents and purposes the level of safety afforded by these two options are the same.

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[3] Plaza B is not the preferred option, and is used only for the purposes of the CRSA.

A qualitative safety analysis of the border plaza options indicates that all of the border plaza options appear to provide an acceptable level of safety. However, Plaza C is the preferred option from a safety perspective because it provides the greatest separation between the plaza and the adjacent interchange, and it introduces a large radius curve that provides a good balance between speed reduction and forward visibility.

Moving forward, the primary road safety issues that should be considered by the design team are:

- In all plaza options, the primary safety concern is the longitudinal speed differential created by a high-speed, 400-series freeway terminating at the border plaza. Measures should be introduced to slow approach speeds to the border plaza, and to structure the expectations of drivers concerning the downstream road and traffic conditions. Treatment of a freeway termination is a significant safety concern, and regardless of which plaza option is selected for the next phase of design, continued safety input should be sought on this issue. Given the significance of the facility, driving simulator studies are recommended once the next phase of design is initiated.
- From a safety perspective one of the main determinants of crash risk on a freeway, or restricted-access facility is the number and configuration of accesses (i.e., interchanges). Crash risk on freeways is highest in the vicinity of the interchange speed change lanes, where merging and diverging create turbulence in the traffic stream. Therefore, safety is enhanced on the mainline by limiting the number of entrances and exits. This is in contrast to the need for accessibility, which encourages appropriately placed access points to connect to the surrounding street network.
- Should the tunnel option be advanced as the preferred design, then a Quantitative Risk Analysis should be conducted to determine whether it is desirable to prohibit DGs movement in the tunnel.
- Should the tunnel option be advanced as the preferred design, than the design team should consider the recommendations contained in Section 6.0 of this report.

8. Examiners Statement

I certify that I have examined the drawings and documents listed in Appendix A, to this Road Safety Assessment Report. The Road Safety Assessment has been carried out with the sole purpose of providing relative safety performance information to the design team and the project owners so that they may make informed decisions concerning the project. I am qualified by my training and experience to undertake road safety assessments and I have not been involved with the design of the alternatives.

Examiner:

Gerry Forbes

Gerry Forbes, M.Eng., P.Eng., P.T.O.E.

March 31, 2009

9. References

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Appendix A: Material Provided to Intus for Review

The following information was made available for the Detroit River International Crossing Study, Comparative Safety Assessment (Conceptual Design Stage):

- Any and all information available on the Detroit River International Crossing Project website (http://www.partnershipborderstudy.com, accessed on October 29, 2006).
- Projected traffic volumes for the AM and PM peak hours of travel in 2035, for all access road alternatives, as provided by URS Canada Inc.
- Conceptual Plaza A Layout and River Crossing Alternatives, prepared by URS Canada Inc., dated: September 7, 2006.
- Conceptual Plaza B Layout and River Crossing Alternatives, prepared by URS Canada Inc., dated: September 7, 2006.
- Conceptual Plaza B1 Layout and River Crossing Alternatives, prepared by URS Canada Inc., dated: September 7, 2006.
- Conceptual Plaza C Layout and River Crossing Alternatives, prepared by URS Canada Inc., dated: September 7, 2006.
- Conceptual Design Plan for Access Road Alternative 1A, prepared by URS Canada Inc., dated: September 7, 2006.
- Conceptual Design Plan for Access Road Alternative 1B, prepared by URS Canada Inc., dated: September 7, 2006.
- Conceptual Design Plan for Access Road Alternative 2A, prepared by URS Canada Inc., dated: September 7, 2006.
- Conceptual Design Plan for Access Road Alternative 2B, prepared by URS Canada Inc., dated: September 7, 2006.
- Conceptual Design Plan for Access Road Alternative 3, prepared by URS Canada Inc., dated: September 7, 2006.
- Conceptual Design Plan for Access Road Alternative 2C (Version 5.3), prepared by URS Canada Inc., dated: February 13, 2008.
- Profile of Highway 401 Extension Alt 3 to Plaza B - Tunnel, prepared by URS Canada Inc., dated: September 7, 2006.
- Profile of Highway 401 Extension Alt 1A to Plaza B – At Grade, prepared by URS Canada Inc., dated: September 7, 2006.
- Profile of Highway 401 Extension Alt 1B to Plaza B – Below Grade, prepared by URS Canada Inc., dated: September 7, 2006.
- Profile of Highway 401 Extension Alt 2A to Plaza B – At Grade, prepared by URS Canada Inc., dated: September 7, 2006.
- Profile of Highway 401 Extension Alt 2B to Plaza B – Below Grade, prepared by URS Canada Inc., dated: September 7, 2006.

- Profile of Highway 401 Extension Alt 2C to Plaza B – Version 5.3 prepared by URS Canada Inc., dated: February 8, 2008.
- Typical Cross-sections for Highway 401 Alternative 2C (Version 5.3) plotted by URS Canada Inc. on February 12, 2008.

Appendix B: The Safety Effects of Open Air Roads Versus Roads in Tunnels

B.1 Definitions

A tunnel is an underground passage that is open to the surface at both ends. The definition of what constitutes a tunnel is not universally agreed upon, but it is generally accepted that tunnels have a minimum length to width ratio of 2:1. In this report, the following terminology will be used:

- Tunnel: An underground passage.
- Tube: A longitudinal compartment that regularly accommodates road users. A tunnel may be made up of one or more tubes.
- Portal: The entrance/exit from the tunnel.
- Unidirectional and bi-directional: Unidirectional means that a tube carries traffic in one direction only; bi-directional means that a tube carries traffic in two opposing directions.

B.2 Crash Risks

The risk of driving in tunnels is different than on open roads, and results from both positive and negative factors that affect crash risk. Elements of tunnel driving that negatively effect safety may include: limited visibility due to tunnel walls, long gradients that increase speeds, reduced offset to the tunnel walls, light changes at the portals, driver inattention in long monotonous tunnels. Moreover, it is much more difficult to control events in a tunnel crash, motorists escape is not simple, and it is harder for emergency response teams (ERTs) to reach the crash site. The positive effects of tunnels on safety include: elimination of adverse weather conditions and variations in lighting, generally a better horizontal and vertical alignment than surface routes, increased driver attention and/or slower speeds due to the confined driving space, increased regulations and legislation concerning vehicle movement, and continuous monitoring of traffic conditions in the tunnel. The overall difference in crash risk between tunnels and open roads is determined by summing the differences between the positive and negative safety impacts of driving in tunnels. It is typical for crash risk to be measured by crash occurrence and severity, and the following literature review encapsulates the conventional wisdom on the crash risk of tunnels versus open roads.

It is important to note that the literature concerning tunnel safety is plentiful, but that the research concerning the relative safety of driving on an open road versus a tunnel is limited. The majority of the literature on tunnel safety concerns tunnel fires, dangerous goods movement through tunnels, and other design, operations, and maintenance issues. The following material provides some data concerning the safety effects of placing a freeway in a tunnel.

Lemke (2000)

Lemke (2000) examined 46 freeway tunnels with unidirectional traffic, and 22 bidirectional road tunnels on rural, two-lane highways in Germany, and compared their safety performance to open roads. The freeway tunnels had an average length of 650 metres, the two-lane highway tunnels had an average length of 800 metres. The period of analysis for each tunnel varied because of different opening dates, and availability of crash data; the average period of analysis was four years. Seven hundred and eighty-four tunnel crashes were used in the analysis, the results are in Table B.1.

TABLE B.1: CRASH RATES FOR TUNNELS VERSUS OPEN ROADS

TYPE OF FACILITY	CASUALTY CRASHES			PROPERTY DAMAGE CRASHES		
	TUNNEL	OPEN ROAD	CRF*	TUNNEL	OPEN ROAD	CRF*
Freeway with hard shoulders	0.074	0.147	0.50	0.326	0.619	0.47
Freeway without hard shoulders	0.130	0.202	0.36	0.354	0.923	0.62
Two-lane Road with two-way traffic	0.141	0.315	0.55	0.249	0.983	0.75

* CRF = Crash reduction factor, or the percentage of crashes that are eliminated by placing an open road in a tunnel (i.e., placing a freeway without hard shoulders in a tunnel results in a 36 percent reduction in casualty crashes)

The results in Table B.1 indicate that the safety performance of roads within a tunnel is better than for similar open roads. Furthermore, the benefits are greatest on roads with two-way traffic. This is to be expected, since tunnels that accommodate two-lane roads are generally constructed in rugged terrain where the tunnels have a better geometric alignment compared to open roads.

If the ratio of damage only to injury crashes is compared (see Table B.2), it can be seen that the proportion of injury crashes is essentially the same for freeways with shoulders in tunnels and on open roads. However, by placing freeways without shoulders, and two-lane roads in tunnels, the severity of crashes tends to increase significantly.

TABLE B.2: RATIO OF DAMAGE ONLY TO INJURY CRASHES

TYPE OF FACILITY	TUNNEL	OPEN ROAD
Freeway with hard shoulders	4.4 to 1	4.2 to 1
Freeway without hard shoulders	2.7 to 1	4.6 to 1
Two-lane Road with two-way traffic	1.8 to 1	3.1 to 1

The Lemke research also revealed that the types of crashes that occur in freeway tunnels are primarily rear-end and sideswipe crashes. In fact, 82 percent of all freeway crashes in tunnels are rear-end and sideswipe crashes. This is to be expected, given the unidirectional flow of traffic, and the lack of conflicting traffic from intersections.

Chang et al (2000)

In a study concerning the safety effects of traffic conditions on freeways Chang et al concluded that "there is no significant difference of accident rates between [open freeways and tunnels]". The study was a retrospective cross-sectional analysis of six years of crash data, with four study sites. This research was conducted on a 4-lane freeway with a 100 km/h design speed in Korea, and traffic volumes of 774 to 5613 vehicles per hour. Two basic freeway sections, and two tunnel freeway sections each with a section length of about two kilometres were used in the analysis. The crash record of the study sites are as shown in Table B.3.

TABLE B.3: NUMBER OF CRASHES IN CHANG ET AL (2000)

YEAR	BASIC 1 (OPEN ROAD)	BASIC 2 (OPEN ROAD)	TUNNEL 1	TUNNEL 2	ALL
1992	3	2	9	4	18
1993	6	5	16	15	42
1994	1	8	16	4	29
1995	4	5	3	3	15
1996	3	4	4	3	14
1997	1	3	3	3	10
All	18	27	51	32	128

The researchers further examined the data by determining the crash rate as a function of congestion (as measured by volume to capacity ratio). The data was regressed to a second-order polynomial function using ordinary-least squares to produce the results shown in Table B.4.

TABLE B.4: CRASH PREDICTION MODELS FOR OPEN ROADS AND TUNNELS

SECTION	MODEL	R-SQUARE
Open Road	$CR = 1493.8(v/c)^2 – 2331.8(v/c) + 1066.5$	0.5161
Tunnel	$CR = 1425.6(v/c)^2 – 2095.8(v/c) + 950.6$	0.5079

The sample size (i.e., number of crashes) used in the Chang research is statistically small and affects the reliability of the results. Nonetheless, assuming the two extremes (v/c = 0 and v/c=1) the CRFs are as shown in Table B.5.

TABLE B.5: CRASH REDUCTION FACTORS (CHANG ET AL, 2000)

	BASIC FREEWAY	TUNNEL	CRF
No. Crashes	45	83	---
Crash Rate (v/c=1)	1066.5	950.6	0.11
Crash Rate (v/c=0)	228.5	280.4	1.23

According to the Chang et al research, the safety effect of tunnelling a freeway is dependent on the level of congestion. In heavily congested conditions a freeway in open-air is safer than a comparable tunnelled freeway. The opposite is true in lightly travelled conditions.

Arends (2003)

Arends (2003) in a review of literature on open road versus tunnel safety reported that studies in France, Germany, and the United States found tunnels generally had lower crash frequencies than open roads. However, the opposite finding was reported for tunnels in the Netherlands. It is also reported that the tunnel crash frequencies are variable, and that even in the studies that presented a general finding that tunnels were safer there were specific instances where tunnel crash rates were higher than the corresponding open roads.

Intus reviewed the referenced American article, and there is no specific information on the relative safety of tunnelled roads versus open roads – this appears to be an error by Arends. The information presented in the Arends article is qualitative, and is not based on original research. Nonetheless, the conflicting results suggest either methodological differences in the various research projects, and/or site specific issues that are influential on crash risk but unaccounted for in the rather broad-brushed analysis.

Salvisberg et al (2004)

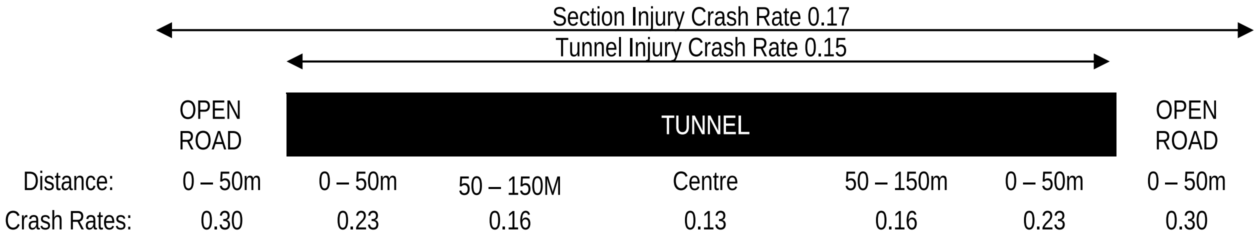
The primary purpose of this research was not to estimate the safety effects of tunnels versus open roads. Hence the data included in this report is limited and not particularly useful for the current purpose. The authors report on the number of crashes on open roads and in tunnels for “nationalstrassen”, but do not account for exposure (either length of network or volume of traffic).

Elvik and Vaa (2004)

Elvik and Vaa did not conduct any new research on tunnel safety, but rather amalgamated existing research to provide insight into the safety performance of tunnels. One of the primary conclusions is that the casualty crash rate in a tunnel is not constant through the length of the tunnel. The crash rates are highest proximate to the portals (see Exhibit B.1). The crash rate is highest on the open road side of the portal likely because:

- This is where the cross-section transitions from the open road standard to the tunnel standard;

- The motorist focuses on the tunnel opening; and
- The open road is usually shaded and is therefore more susceptible to slippery and icy road conditions.



Adapted from: Amundsen and Ranes (1997)

EXHIBIT B.1: INJURY CRASH RATES IN TUNNELS (CRASHES/MILLION-VEHICLE KILOMETRES)

Elvik and Vaa also conducted a meta-analysis on several Norwegian and one Swiss study on the relative safety of tunnel versus open road facilities, and estimate the crash reduction factors (CRFs) shown in Table B.6.

TABLE B.6: SAFETY EFFECT OF PLACING AN OPEN ROAD IN A TUNNEL (ELVIK AND VAA, 2004)

ROAD TYPE	CRF	95% CONFIDENCE INTERVAL
Class A Motorways	0.02	0.15 to -0.12*
Rural roads	0.04	0.17 to -0.11
Urban roads	0.61	0.77 to 0.35

*A negative CRF indicates that crashes increase with the intervention. For example, a CRF of –0.12 indicates a 12 percent increase in crash occurrence.

The results show that there is a statistically significant safety benefit to placing an urban road in a tunnel, but that the crash rate on an open air freeway is comparable to a tunneled freeway.

Robatsch and Nussbaumer (2005)

This Austrian research reports on the relative safety of motorways (i.e., freeways) versus road tunnels and finds that tunnelling motorways reduces injury and overall crash rates, but increases fatality crash risk (see Table B.7).

TABLE B.7: CRASH REDUCTION FACTORS FOR TUNNELED ROADS (ROBATSCH AND NUSSBAUMER, 2005)

CRASH SEVERITY	AUTOBAHN	TUNNEL	CRF
Crash rate	0.137	0.104	0.24
Injury crash rate	0.224	0.186	0.17
Fatality rate	7.4	15.4	2.08

The above statistics are slightly obscured for the purposes of this review, since the tunnel data is for all roads, and not necessarily freeways. In this same report, the data are parsed further for unidirectional and bidirectional tunnels. If the unidirectional tunnels are assumed to be freeways, and the crash rates for unidirectional tunnels are compared to those for autobahns, the safety effects of tunnelled freeways are less pronounced (see Table B.8).

TABLE B.8: CRASH REDUCTION FACTORS FOR TUNNELED FREEWAYS (ROBATSCH AND NUSSBAUMER, 2005)

	AUTOBAHN	UNI-DIRECTIONAL TUNNEL	CRF
Crash rate	0.137	0.118	0.14
Injury crash rate	0.224	0.185	0.17
Fatality rate	7.4	11.6	1.57

OECD (2006)

In OECD (2006), it is reported that a Swiss study comprised of eight years of crash data revealed that the average crash rate in tunnels is 0.35 crashes/MVK, compared to 0.47 crashes/MVK on open roads (CRF = 0.26). No further details concerning the study methodology or data set are provided, and the original source document is in German. Again, it is important to be able to distinguish between the safety impacts of roads placed in tunnels, and freeways placed in tunnels.

B.3 Discussion

Despite the important role that tunnels serve in the global transportation scenario, it is surprising to see how little research has been conducted to measure the safety impacts of tunneling roads. For the purposes of this effort, the knowledge base is diminished further because much of the research was documented in foreign language reports.

One must be very careful in interpreting the results presented in the literature review, and in applying the results to the Windsor situation. Firstly, the majority of the research on tunnel safety seems to be oriented towards rural conditions, and tunnels that are used to traverse mountains, bodies of water, and other rugged terrain. This is not directly comparable to the Windsor situation where the tunnel is being proposed to traverse and protect an urbanized area and will follow the same general horizontal alignment as the at-grade alternatives. In addition, the Windsor situation involves a freeway that is not directly comparable to the two-lane highways that are the subject of many of the above-mentioned studies.

Tunnels that accommodate freeways in urban areas are acceptable infrastructure around the world, and there is no reason to exclude the tunnel option from consideration solely on the basis of expected safety performance. In fact, the collected evidence suggests that placing an urban freeway in a tunnel should result in a safety performance that is similar to that of a surface freeway. The research that has examined the safety effects of tunnelled freeways is summarized in Table B.9.

TABLE B.9: SUMMARY OF RESEARCH CONCERNING THE SAFETY EFFECTS OF TUNNELLING FREEWAYS

AUTHOR	CRASH TYPE	NO. CRASHES		CRASH RATE		EFFECT (CRF)
		OPEN ROAD	TUNNEL	OPEN ROAD	TUNNEL	
Mo (1980)*	Injury	158	8	0.072	0.302	4.21
Thoma (1989)*	Injury	3319	207	0.143	0.132	0.08
	PDO	7753	408	0.334	0.260	0.22
Lemke (2000)	Injury	---	204	0.147	0.074	0.50
	PDO	---	453	0.619	0.326	0.47
Chang et al (2000)	All (v/c=0)	45	83	228.5	280.4	1.23
	All (v/c=1)	45	83	1066	951	0.11
R&N (2005)	Injury	---	---	0.137	0.118	0.14
	All	---	275	0.224	0.185	0.17
OECD (2006)	All	---	---	0.47	0.35	0.26

*The Mo (1980) and Thoma (1989) studies are the individual studies that are included in the Elvik and Vaa (2000) meta-analysis. Source data from each study was obtained by Intus from Rune Elvik of Norway.

If the Mo (1980) and Chang et al (2000) studies are omitted from consideration there is a very clear trend in the research suggesting that placing a freeway in a tunnel provides some safety benefit. The magnitude of the benefit is a little less clear. Furthermore, while ignoring the Mo and Chang et al results is not completely appropriate, the confidence that should be placed on these studies should be small given the relatively small crash counts used in each study.

Ideally, the disparate results would be combined in a meta-analysis (as done by Elvik and Vaa) to yield a best estimate with associated confidence intervals. However, none of the above-cited research includes the necessary background data for such an analysis. Consequently, a more subjective qualitative approach is employed.

The Lemke research produced the largest crash reductions and specifically addresses the relative safety of freeways with hard shoulders in tunnels. It is difficult to understand the etiology that would cause a dramatic (i.e., 50 percent) reduction in crashes simply by placing an urban freeway in a tunnel. Many of the causal factors in urban crashes, such as pedestrians, intersections, private driveways, etc., are not present on freeways whether they are in a tunnel or not. The only realistic differences between open-road and tunneled freeways are the controlled driving environment of the tunnel (i.e., consistent light and weather), and a potential increase in driver vigilance in tunnel situations.

A more plausible explanation for the large safety benefit of the tunnelled freeways was uncovered through personal contact with Dr. Lemke by Intus. The crash rates used for open road sections of freeway in the Lemke analysis are the general/generic rates used in highway planning and design. These average rates would include sections of freeway that have exits and entries, whereas the tunnelled freeways probably do not have these features (or at least have fewer of them). The difference in exits/entries between the two comparators is likely the principle reason for the dramatic difference in safety performance.

At the other end of the spectrum, the Mo and Chang et al research yield results that suggest the safety performance of tunnelled freeways is the same or worse than open-air freeways. As previously mentioned, the confidence in these results should be commensurate with the variance in the data (i.e., a low number of crashes produces a large variance in the result, inspiring lower confidence).

The remaining research, which appears to be reliable, has yielded safety benefits from tunnelled freeways that range from 8% to 26%. Therefore, the qualitative analysis might suggest that a freeway in a tunnel is 8 to 26% safer than a similar open-air facility. However, if the Mo and Chang et al research are also considered (but not weighted heavily), then the responsible conclusion would be that the safety benefit is closer to the lower end of the range. On this basis, the best interpretation of the research on open road versus tunneled freeways is that the safety performance of a tunnel section is about 10 percent lower than a comparable open road section.

Before this conclusion is put into practice, it is noted that the DRIC project includes intermediate portals that may have a significant impact on safety performance. The impact of intermediate portals on safety performance is explored further in the next section.

B.4 Entries and Exits in Tunnels

One of the chief safety concerns regarding freeways in tunnels is the combined effect that the alignment (i.e., sight distances) and the confined driving environment will have on the crash risk at intermediate exits and entries. Most of the world’s tunnels have two portals – one at either end, with no intermediate portals (i.e., entries or exits) – although this is not always the case. The provision of ramps in tunnels is not inherently “unsafe”, and is an accepted geometric design practice. Projects that are planned, or have been constructed to include ramps in tunneled sections include: the Central Artery Tunnel in Boston (United

States), the Cross-City Tunnel in Sydney (Australia), North-South Bypass Tunnel in Brisbane (Australia), the Kallang/Paya-Lebar Expressway (KPE) in Singapore, and the Autoroute Ville-Marie Tunnel in Montreal (Canada). The Central Artery Tunnel includes seven exits; three of which are located within a 1.2 kilometre section of the southbound tunnel. The KPE includes 4 interchanges within 9 kilometres of tunnel.

Despite the forgoing, the safety performance of ramps in tunnels has not been extensively studied. There is no reference crash data that can be used to determine if mainline merge, diverge, and/or weaving areas caused by entrance and exit ramps in the tunnel significantly affect safety performance. In a literature review regarding the effects of tunnel characteristics on driving behaviour Martens and Kaptein (1997) confirm this by stating that "drivers do not really expect entries and exits in tunnels" but that "it is unclear whether…merging inside a tunnel would result in dangerous situations."

As a result of the above review Martens and Kaptein initiated a driver simulator study to investigate the effects on driver behaviour of different sight distances for accesses inside tunnels [Martens and Kaptein, 1998]. The study included a sample of experienced drivers (>5 years of driving experience) exiting and entering the mainline of a roadway both in open air (control) and tunnel (experimental) situations. The researchers tested the following variables:

- Sight distance in the tunnel: 100 metres, 150 metres, and 300 metres
- Shoulder: Present or absent
- Traffic volume: high or low
- Exit/entry configuration: single exit/entry or weave (entry followed by exit)

Except for available sight distance, the road design standards for open roads were applied to the tunnel (i.e., acceleration lane = 350 metres, exit lane = 250 metres, and weaving areas = 600 metres). During high volume conditions, the mainline traffic drove at 100 km/h; during light volume conditions, the mainline traffic drove at 110 km/h. Driving behaviour was measured by driving speed, accepted gap, time-to-crash, and position where the lane change was initiated.

With respect to entries, all subjects performed the merge in time. The only difference in driver behaviour between the open air and tunnel merges was that the merge was initiated earlier in tunnels (about 20 metres). With respect to exits, all subjects performed the required manoeuvre in time. The only observed difference between open air and tunnel diverges was that driving speeds in the tunnel were slightly slower than in open-air conditions (up to 4 km/h). In all of the tunnels scenarios available sight distance did not affect driver behaviour on either entries or exits from the mainline.

The researchers conclude that no unsafe driving situations occurred and that all manoeuvres were completed in a relatively safe manner. Therefore, it does not appear that any enhanced standards are required for tunnels entries and exits.

In a more recent effort, Carpenter et al (2001) conducted a study of signing issues on tunnel exits in the Central Artery Tunnel Project. The research methodology was a driver simulator study investigating exit manoeuvres in the tunnel under different driving conditions. There were several missed exits, late exits, and double lane changes that the researchers attribute to obstruction of signing from large trucks, and tunnel alignment. The researchers allude to, and it is reasonable to state that missed and late exits are safety issues that would translate into a higher crash frequency – what is not clear is the magnitude of the increase.

It is important to note that in the Carpenter et al research the signing conditions that were investigated were applicable to a location-specific exit in the tunnel where the guide signing was sub-standard with respect to placement. In fact, the advance guide sign (when present) was located only 400 metres upstream of the exit (the US guidelines recommend an advance guide sign be placed 1.6 km upstream of the exit). However, the Ontario guideline for advance guide sign placement recommends placement 370 to 460 metres upstream, so the Carpenter et al research has significance to the DRIC project.

The conventional wisdom on intermediate tunnel exits and entries is formed by two conflicting studies. Martens and Kaptein (1998) conclude that driver behaviour at merges and diverges within tunnels is comparable to driving behaviour on open roads under similar conditions. The Carpenter et al (2001) research demonstrates some safety issues with missed exits and late exiting when exits are closely-spaced in a tunnel.

In the latter study there is no direct comparison of exits and entries in tunnels to those on open roads. Given that the Carpenter et al research was structured to address a specific condition (sub-standard sign placement) it is difficult to translate this research to other conditions. However, the Carpenter et al research does make some important, translatable observations, such as the limited space in tunnels requiring compromises in sign size or placement. Reduced overhead clearances will limit the ability to use large signs placed over the traveled lanes, and sign obstruction by large trucks is more prominent in tunnels.

On the other hand, the Martens and Kaptein work included a variety of geometric designs, and traffic conditions in a direct comparison between open air and tunnel driving. It is certainly the more robust data, and the best available evidence concerning the safety effects of intermediate entries and exits in tunnels. Therefore, while intermediate entries and exits are relatively unexpected in tunnels, the effect of these ramps on driver behaviour (and hence safety) is negligible if the design standards for open-air roads are applied.

Still, it is troublesome to generalize the Martens and Kaptein research, and apply it to DRIC (or any other situation) because there does not appear to be any consideration of traffic signing difficulties and the influence of unfamiliar drivers (the very issue studied by Carpenter et al). Tunnels have limited space for traffic signing, and freeway guide signs in open-air are relatively large signs. The DRIC will have a significant number of unfamiliar drivers, and the information provided by the guide signing will be important for error-free driving by these unfamiliar drivers.

So in terms of roadway geometry, as long as similar sight distances and acceleration/deceleration lengths can be provided, the safety performance of the exits and entrances in the tunnel are expected to be similar to these facilities in open-air. However, in terms of traffic control devices (advance guide signs in particular), the restricted space in the tunnel may cause some compromises in sign size, placement, and/or visibility. If no compromises are imminent, then the safety performance will be similar to open roads. If signing compromises are required (and this is likely the case), then a negative effect on crash risk is expected. The magnitude of the increase in crash risk is inconclusive.

B.5 Conclusion

The net difference in the crash risk between the open road and tunnel alternatives of the DRIC project is determined by considering the global research on this topic, and adjusting the results based on location-specific tunnel features that also influence crash risk. Adjustments to global research results are mainly required because intermediate tunnel entries and exits are not typical of studied tunnels, and are safety relevant. In fact, the area proximate to entries and exits are the locations with the highest crash risk along the mainline of traditional freeways, so it is expected that the entries and exits will have a significant effect on the overall safety performance of the tunnel.

Given the number and configuration of entries and exits for the tunnel alternative of the DRIC, the best estimate of the effect of the tunnel on safety performance is a net zero decrease in crash risk. The safety benefits of tunnelling the freeway, that are exhibited in the global research, are offset by the safety detriments introduced by placing the entries and exits in restricted spaces that limit signing options for unfamiliar drivers.

Appendix C: Crash Modification Factors for One-way Streets

In lieu of a crash prediction model for the one-way service roads in Alternatives 1A and 1B, the safety performance of these road sections are calculated using the crash prediction models for two-way streets, and then adjusting the results using a crash modification factor for two-way to one-way street conversion. The following is the rationale for the one-way street crash reduction factor.

The conventional wisdom concerning one-way streets is that one-way streets are measurably safer than two-way streets because of reduced conflicts, and decreased mental workload on drivers. While most one-way streets are introduced as a measure to combat congestion in a corridor the safety benefits of conversion have also been touted by transportation professionals. However, the claims of increased safety from one-way streets have not been widely researched.

The general source for crash modification factors is Provincial/Territorial and State manuals respecting road safety reviews and crash countermeasure implementation. Two such sources were found to contain information on one-way street conversion. Agent et al (1996) developed CMFs for the State of Kentucky using a combination of literature reviews and surveys of practice among the States. They concluded, based on responses from three States and no relevant literature that a two-way to one-way street conversion reduces crashes in the range of 30 to 40 percent, with an average reduction of 33 percent. Similarly, Gan et al (2005) using a similar approach for the State of Florida recommends crash reductions of 26 percent for intersection crashes and 43 percent for mid-block crashes. Both of these researchers have no underlying scientific basis for the reported crash reductions.

The most reliable source of information concerning the safety impacts of one-way street conversion is produced by Elvik and Vaa (2004). The crash modification factors recommended in Table C.1 were produced by conducting a meta-analysis of six research studies on the conversion of two-way to one-way operation. A meta-analysis is a powerful tool that permits the amalgamation of the results from several disparate research studies into a single result with increased reliability and accuracy. For this reason, and given that the analysis includes the six identifiable articles concerning the safety impacts of one-way street, the crash reduction factors by Elvik and Vaa are considered to be the best information available at this time.

Despite popular thought that one-way street conversion significantly reduces crash occurrence, the best evidence suggests that injury crashes are not statistically different from two-way streets, and there is about an eight percent reduction in property damage only crashes. Therefore, a crash reduction factor of +1% and –8% for injury causing crashes and property damage crashes respectively will be used in the comparative safety analysis.

TABLE C.1: CRASH REDUCTION FACTORS FOR ONE-WAY STREET CONVERSION

CRASH SEVERITY	BEST ESTIMATE OF CRF (%)	95% CONFIDENCE INTERVAL
Injury	+ 1	-11 to +14
Property damage only	- 8	-12 to -5

Appendix D: Safety Performance Analysis Outputs

ALTERNATIVE 1A - At-grade facility with one-way service roads

RAMPS	DIR'N	OFF/ON	RAMP TYPE	ADT	MODEL	L (KM)	F&I	PDO
Highway 3	NB	Off	Flared	9940	Ramp	0.59	0.3	1.3
		On	Flared	6950	Ramp	0.64	0.2	0.9
	SB	Off	Flared	6350	Ramp	0.77	0.2	0.9
		On	Flared	7020	Ramp	0.62	0.2	0.9
St. Clair College	NB	Off	Flared	3530	Ramp	0.41	0.1	0.5
		On	Flared	4010	Ramp	0.41	0.1	0.5
	SB	Off	Flared	7010	Ramp	0.41	0.2	0.9
		On	Flared	3540	Ramp	0.41	0.1	0.4
HCR	NB	Off	Flared	7780	Ramp	0.43	0.3	1.0
	SB	On	Flared	8320	Ramp	0.79	0.2	1.1
Malden	NB	On	Flared	2600	Ramp	0.41	0.1	0.3
	SB	Off	Flared	4000	Ramp	0.49	0.1	0.6
EC Row	SB	Off	Flared	10210	Ramp	0.82	0.4	1.4
Ojibway	NB	Off	Flared	2500	Ramp	0.34	0.1	0.4
		On	Loop	500	Ramp	0.23	0.0	0.1
	SB	Off	Loop	1600	Ramp	0.34	0.1	0.2
		On	Flared	9500	Ramp	0.42	0.2	0.9
EC Row	NB	Off	Flared	2850	Ramp	1.12	0.1	0.5
Total							*3.0*	*12.8*

MAINLINE				ADT	MODEL	L (KM)	F&I	PDO
Plaza	Ojibway			25680	Freeway	0.32	0.4	1.0
Ojibway	EC Row On Ramp			35580	Freeway	0.77	1.4	4.0
EC Row On Ramp	Malden			25370	Freeway	0.42	0.5	1.4
Malden	HCR			18770	Freeway	1.72	1.3	3.6
HCR	St. Clair College			34870	Freeway	2.98	5.3	15.1
St. Clair College	Highway 3			30920	Freeway	3.07	4.6	13.1
Total							*13.5*	*38.2*

HURON CHURCH ROAD				ADT	MODEL	L (KM)	F&I	PDO
College	Girardot			27030	Arterial	0.45	0.8	2.8
Girardot	Tecumseh			23950	Arterial	0.57	0.9	3.2
Tecumseh	Dorchester			29850	Arterial	0.29	0.7	2.8
Dorchester	Prince/Totten			31140	Arterial	0.24	0.6	2.5
Prince/Totten	Malden			36110	Arterial	0.38	0.8	3.0
Malden	Industrial			29180	Arterial	0.90	1.6	6.0
Industrial	EC Row1			32670	Arterial	0.40	0.8	2.9
EC Row 1	EC Row 2			31600	Arterial	0.30	0.6	2.1
Total							*6.8*	*25.4*

HCR INTERSECTIONS			ADT_{HCR}	ADT_{INT}	MODEL	LEGS	F&I	PDO
College			23970	5690	Signal	4	2.3	5.8
Girardot			24980	2040	Signal	4	1.7	4.1
Tecumseh			28610	8150	Signal	4	3.2	8.0
Dorchester			30500	1870	Signal	4	2.0	5.0
Prince/Totten			33860	4940	Signal	4	3.2	8.0
Malden			32570	6400	Signal	4	3.4	8.5
Industrial			30980	4960	Signal	4	2.9	7.3
EC Row 1			26070	4240	Ramp Term	3	0.1	0.5
EC Row 2			24180	950	Ramp Term	3	0.0	0.2
Total							*19.0*	*47.5*

HURON CHURCH ROAD			ADT_{N}	ADT_{S}	MODEL	L (KM)	F&I	PDO
EC Row 2	Labelle		20100	24200	Arterial	0.39	0.6	2.1
Labelle	Grand Marais		18600	23800	Arterial	0.54	0.8	2.7
Grand Marais	Pulford		17800	22200	Arterial	0.55	0.7	2.7
Pulford	Todd/Cabana		18000	22500	Arterial	0.75	1.0	3.7
Todd/Cabana	Huron Church Line		17700	18800	Arterial	0.21	0.3	0.9
Huron Church Line	St. Clair College		9000	12500	Arterial	1.28	1.0	3.7
St. Clair College	Cousineau		11400	13600	Arterial	0.53	0.5	1.7
Cousineau	Howard		11400	10800	Arterial	1.60	1.3	4.7
Sub-Total							6.1	22.2
Apply One-way CRFs +1% F&I; -8% PDO							*6.2*	*20.5*

HCR INTERSECTIONS			ADT_{HCR}	ADT_{INT}	MODEL	LEGS	F&I	PDO
Labelle			17770	530	Unsig	3	0.2	0.5
Grand Marais Loop at HCR			7880	2460	Unsig	3	0.1	0.3
Grand Marais at Loop			7320	1680	Unsig	3	0.1	0.2
Pulford			9780	170	Unsig	3	0.1	0.2
Todd/Cabana N			4540	16600	Signal	4	1.4	3.5
Todd/Cabana S			7050	17380	Signal	4	1.8	4.4
Huron Church Line at Todd			17860	7180	Signal	3	1.3	3.2
St. Clair College N			8910	3650	Signal	4	0.7	1.6
St. Clair College S			10820	2160	Unsig	3	0.2	0.4
Cousineau N			6640	8710	Signal	4	0.8	2.0
Cousineau S			8460	11780	Signal	4	1.2	3.0
Howard N			9940	11020	Signal	4	1.2	3.0
Howard S			3940	18430	Signal	4	1.5	3.8
Total							*10.6*	*26.1*

GRAND TOTAL							59	171

ALTERNATIVE 1B - Below grade facility with one-way service roads

RAMPS	DIR'N	OFF/ON	RAMP TYPE	ADT	MODEL	L (KM)	F&I	PDO
Highway 3	NB	Off	Flared	9940	Ramp	0.59	0.3	1.3
		On	Flared	6950	Ramp	0.64	0.2	0.9
	SB	Off	Flared	6350	Ramp	0.77	0.2	0.9
		On	Flared	7020	Ramp	0.62	0.2	0.9
St. Clair College	NB	Off	Flared	3530	Ramp	0.41	0.1	0.5
		On	Flared	4010	Ramp	0.41	0.1	0.5
	SB	Off	Flared	7010	Ramp	0.41	0.2	0.9
		On	Flared	3540	Ramp	0.41	0.1	0.4
Cabana	NB	On	Flared	6000	Ramp	0.44	0.1	0.6
	SB	Off	Flared	7200	Ramp	0.44	0.2	1.0
HCR	NB	Off	Flared	13780	Ramp	0.43	0.4	1.7
	SB	On	Flared	13120	Ramp	0.98	0.3	1.9
Malden	NB	On	Flared	1100	Ramp	0.41	0.0	0.2
	SB	Off	Flared	1900	Ramp	0.49	0.1	0.3
EC Row	SB	Off	Flared	12000	Ramp	0.82	0.4	1.6
Ojibway	NB	Off	Flared	2700	Ramp	0.34	0.1	0.4
		On	Loop	400	Ramp	0.23	0.0	0.1
	SB	Off	Loop	1600	Ramp	0.34	0.1	0.2
		On	Flared	6700	Ramp	0.42	0.2	0.7
EC Row	NB	Off	Flared	2850	Ramp	1.12	0.1	0.5
Total							*3.6*	*15.5*

MAINLINE				ADT	MODEL	L (KM)	F&I	PDO
Plaza	Ojibway			30560	Freeway	0.32	0.5	1.3
Ojibway	EC Row On Ramp			37960	Freeway	0.77	1.5	4.4
EC Row On Ramp	Malden			25960	Freeway	0.42	0.5	1.4
Malden	HCR			22960	Freeway	1.72	1.7	4.8
HCR	St. Clair College			49860	Freeway	2.98	8.9	25.1
St. Clair College	Highway 3			35700	Freeway	3.07	5.7	16.1
Total							*18.8*	*53.1*

HURON CHURCH ROAD				ADT	MODEL	L (KM)	F&I	PDO
College	Girardot			27030	Arterial	0.45	0.8	2.8
Girardot	Tecumseh			23950	Arterial	0.57	0.9	3.2
Tecumseh	Dorchester			29850	Arterial	0.29	0.7	2.8
Dorchester	Prince/Totten			31140	Arterial	0.24	0.6	2.5
Prince/Totten	Malden			36110	Arterial	0.38	0.8	3.0
Malden	Industrial			29180	Arterial	0.90	1.6	6.0
Industrial	EC Row1			32670	Arterial	0.40	0.8	2.9
EC Row 1	EC Row 2			31410	Arterial	0.30	0.6	2.1
Total							*6.8*	*25.4*

HCR INTERSECTIONS			ADT$_{HCR}$	ADT$_{INT}$	MODEL	LEGS	F&I	PDO
College			23970	5690	Signal	4	2.3	5.8
Girardot			24980	2040	Signal	4	1.7	4.1
Tecumseh			28610	8150	Signal	4	3.2	8.0
Dorchester			30500	1870	Signal	4	2.0	5.0
Prince/Totten			33860	4940	Signal	4	3.2	8.0
Malden			32570	6400	Signal	4	3.4	8.5
Industrial			30980	4960	Signal	4	2.9	7.3
EC Row 1			26070	4240	Ramp Term	3	0.1	0.5
EC Row 2			24180	950	Ramp Term	3	0.0	0.2
Total							*19.0*	*47.5*

HURON CHURCH ROAD			ADT$_{N}$	ADT$_{S}$	MODEL	L (KM)	F&I	PDO
EC Row 2	Labelle		20100	24200	Arterial	0.39	0.6	2.1
Labelle	Grand Marais		18600	23800	Arterial	0.54	0.8	2.7
Grand Marais	Pulford		17800	22200	Arterial	0.55	0.7	2.7
Pulford	Todd/Cabana		18000	22500	Arterial	0.75	1.0	3.7
Todd/Cabana	Huron Church Line		17700	18800	Arterial	0.21	0.3	0.9
Huron Church Line	St. Clair College		9000	12500	Arterial	1.28	1.0	3.7
St. Clair College	Cousineau		11400	13600	Arterial	0.53	0.5	1.7
Cousineau	Howard		11400	10800	Arterial	1.60	1.3	4.7
Sub-Total							6.1	22.2
Apply One-way CRFs +1% F&I; -8% PDO							*6.2*	*20.5*

HCR INTERSECTIONS			ADT_{HCR}	ADT_{INT}	MODEL	LEGS	F&I	PDO
Labelle N			17890	3540	Signal	4	1.4	3.5
Labelle S			16740	2880	Signal	4	1.2	3.0
Grand Marais N			4420	4650	Unsig	4	1.0	2.4
Grand Marais S			3550	3060	Unsig	4	0.8	1.9
Pulford N			5290	1080	Unsig	4	0.5	1.2
Pulford S			3110	840	Unsig	4	0.4	0.9
Todd/Cabana N			6940	14680	Signal	4	1.5	3.6
Todd/Cabana S			10410	17380	Signal	4	2.0	5.1
Huron Church Line N			5280	2400	Signal	3	0.9	2.3
Huron Church Line S			10980	3960	Signal	4	0.9	2.1
St. Clair College N			8910	3650	Signal	4	0.7	1.6
St. Clair College S			10820	2160	Unsig	3	0.2	0.4
Cousineau N			6640	8710	Signal	4	0.8	2.0
Cousineau S			8460	11780	Signal	4	1.2	3.0
Howard N			9940	11020	Signal	4	1.2	3.0
Howard S			3940	18430	Signal	4	1.5	3.8
Total							*16.2*	*39.8*

GRAND TOTAL						71	202

ALTERNATIVE 2A - At grade facility along side Huron Church Road

RAMPS	DIR'N	OFF/ON	RAMP TYPE	ADT	MODEL	L (KM)	F&I	PDO
Highway 3	NB	Off	Flared	9940	Ramp	0.61	0.3	1.3
		On	Flared	7090	Ramp	0.64	0.2	0.9
	SB	Off	Flared	6470	Ramp	0.39	0.2	0.9
		On	Flared	7020	Ramp	1.04	0.2	1.3
Todd	NB	Off	Flared	5470	Ramp	0.57	0.2	0.8
		On	Flared	8980	Ramp	0.59	0.2	1.0
	SB	Off	Flared	11170	Ramp	0.54	0.4	1.4
		On	Flared	4330	Ramp	0.92	0.1	0.8
HCR	NB	Off	Flared	16430	Ramp	0.41	0.5	2.0
	SB	On	Flared	12150	Ramp	0.68	0.3	1.4
Malden	NB	On	Flared	1100	Ramp	0.41	0.0	0.2
	SB	Off	Flared	1900	Ramp	0.49	0.1	0.3
EC Row	SB	Off	Flared	13000	Ramp	0.82	0.5	1.8
Ojibway	NB	Off	Flared	2700	Ramp	0.34	0.1	0.4
		On	Loop	400	Ramp	0.23	0.0	0.1
	SB	Off	Loop	1600	Ramp	0.34	0.1	0.2
		On	Flared	6700	Ramp	0.42	0.2	0.7
EC Row	NB	Off	Flared	1000	Ramp	1.12	0.1	0.2
Total							*3.5*	*15.5*

MAINLINE				ADT	MODEL	L (KM)	F&I	PDO
Plaza	Ojibway			29750	Freeway	0.32	0.5	1.3
Ojibway	EC Row On Ramp			37150	Freeway	0.77	1.5	4.2
EC Row On Ramp	Malden			24150	Freeway	0.42	0.4	1.3
Malden	HCR			21480	Freeway	1.72	1.5	4.4
HCR	Cabana			50060	Freeway	1.40	4.2	11.9
Cabana	Highway 3			39710	Freeway	4.65	10.0	28.3
Total							*18.2*	*51.4*

HURON CHURCH ROAD				ADT	MODEL	L (KM)	F&I	PDO
College	Girardot			27510	Arterial	0.45	0.8	2.8
Girardot	Tecumseh			24160	Arterial	0.57	0.9	3.2
Tecumseh	Dorchester			30380	Arterial	0.29	0.7	2.8
Dorchester	Prince/Totten			31630	Arterial	0.24	0.6	2.6
Prince/Totten	Malden			36730	Arterial	0.38	0.8	3.1
Malden	Industrial			28040	Arterial	0.90	1.6	5.8
Industrial	EC Row1			31380	Arterial	0.40	0.8	2.8
EC Row 1	EC Row 2			34280	Arterial	0.30	0.6	2.3
Total							*6.9*	*25.5*

HCR INTERSECTIONS	ADT_{HCR}	ADT_{INT}	MODEL	LEGS	F&I	PDO
College	24250	5090	Signal	4	2.3	5.6
Girardot	25210	2040	Signal	4	1.7	4.2
Tecumseh	28250	8280	Signal	4	3.2	8.0
Dorchester	31000	1870	Signal	4	2.0	5.1
Prince/Totten	34520	4380	Signal	4	3.2	7.9
Malden	32640	5770	Signal	4	3.3	8.2
Industrial	29740	4050	Signal	4	2.6	6.5
EC Row 1	25300	5330	Ramp Term	3	0.1	0.6
EC Row 2	28320	420	Ramp Term	3	0.0	0.1
Total					*18.4*	*46.1*

HURON CHURCH ROAD		ADT_N	ADT_S	MODEL	L (KM)	F&I	PDO
EC Row 2	Spring Garden	20100	24200	Arterial	0.39	0.6	2.1
Spring Garden	Grand Marais	18600	23800	Arterial	0.54	0.8	2.7
Grand Marais	Pulford	17800	22200	Arterial	0.55	0.7	2.7
Pulford	Todd/Cabana	18000	22500	Arterial	0.75	1.0	3.7
Todd/Cabana	Huron Church Line	17700	18800	Arterial	0.21	0.3	0.9
Huron Church Line	St. Clair College	9000	12500	Arterial	1.28	1.0	3.7
St. Clair College	Cousineau	11400	13600	Arterial	0.53	0.5	1.7
Cousineau	Howard	11400	10800	Arterial	1.60	1.3	4.7
Total						*6.1*	*22.2*

HCR INTERSECTIONS		ADT_{HCR}	ADT_{INT}	MODEL	LEGS	F&I	PDO
Spring Garden		32460	6440	Signal	4	3.4	8.5
Labelle		8730	1760	Signal	3	0.9	2.3
Grand Marais Loop at HCR		9330	2340	Signal	3	1.0	2.4
Grand Marais at Loop		3140	3510	Unsig	3	0.1	0.1
Pulford		8750	1890	Signal	3	0.9	2.3
Todd/Cabana N		13900	19790	Signal	4	2.6	6.5
Huron Church Line		16830	5280	Signal	3	1.2	3.0
St. Clair College N		9820	2610	Signal	3	1.0	2.5
Cousineau S		10700	9540	Signal	4	1.2	2.9
Howard S		14780	11330	Signal	4	1.8	4.4
401 Ramp at Howard		22970	3300	Ramp Term	4	0.0	0.2
Total						*14.1*	*35.1*

GRAND TOTAL						67	196

ALTERNATIVE 2B - Below grade facility along side Huron Church Road

RAMPS	DIR'N	OFF/ON	RAMP TYPE	ADT	MODEL	L (KM)	F&I	PDO
Highway 3	NB	Off	Flared	9940	Ramp	0.61	0.3	1.3
		On	Flared	7090	Ramp	0.64	0.2	0.9
	SB	Off	Flared	6470	Ramp	0.39	0.2	0.9
		On	Flared	7020	Ramp	1.04	0.2	1.3
Todd	NB	Off	Flared	5470	Ramp	0.57	0.2	0.8
		On	Flared	8980	Ramp	0.59	0.2	1.0
	SB	Off	Flared	11170	Ramp	0.54	0.4	1.4
		On	Flared	4330	Ramp	0.92	0.1	0.8
HCR	NB	Off	Flared	16430	Ramp	0.41	0.5	2.0
	SB	On	Flared	12150	Ramp	0.68	0.3	1.4
Malden	NB	On	Flared	1100	Ramp	0.41	0.0	0.2
	SB	Off	Flared	1900	Ramp	0.49	0.1	0.3
EC Row	SB	Off	Flared	13000	Ramp	0.82	0.5	1.8
Ojibway	NB	Off	Flared	2700	Ramp	0.34	0.1	0.4
		On	Loop	400	Ramp	0.23	0.0	0.1
	SB	Off	Loop	1600	Ramp	0.34	0.1	0.2
		On	Flared	6700	Ramp	0.42	0.2	0.7
EC Row	NB	Off	Flared	1000	Ramp	1.12	0.1	0.2
Total							*3.5*	*15.5*

MAINLINE				ADT	MODEL	L (KM)	F&I	PDO
Plaza	Ojibway			29750	Freeway	0.32	0.5	1.3
Ojibway	EC Row On Ramp			37150	Freeway	0.77	1.5	4.2
EC Row On Ramp	Malden			24150	Freeway	0.42	0.4	1.3
Malden	HCR			21480	Freeway	1.72	1.5	4.4
HCR	Cabana			50060	Freeway	1.40	4.2	11.9
Cabana	Highway 3			39710	Freeway	4.65	10.0	28.3
Total							*18.2*	*51.4*

HURON CHURCH ROAD				ADT	MODEL	L (KM)	F&I	PDO
College	Girardot			27510	Arterial	0.45	0.8	2.8
Girardot	Tecumseh			24160	Arterial	0.57	0.9	3.2
Tecumseh	Dorchester			30380	Arterial	0.29	0.7	2.8
Dorchester	Prince/Totten			31630	Arterial	0.24	0.6	2.6
Prince/Totten	Malden			36730	Arterial	0.38	0.8	3.1
Malden	Industrial			28040	Arterial	0.90	1.6	5.8
Industrial	EC Row1			31380	Arterial	0.40	0.8	2.8
EC Row 1	EC Row 2			34280	Arterial	0.30	0.6	2.3
Total							*6.9*	*25.5*

HCR INTERSECTIONS			ADT_{HCR}	ADT_{INT}	MODEL	LEGS	F&I	PDO
College			24250	5090	Signal	4	2.3	5.6
Girardot			25210	2040	Signal	4	1.7	4.2
Tecumseh			28250	8280	Signal	4	3.2	8.0
Dorchester			31000	1870	Signal	4	2.0	5.1
Prince/Totten			34520	4380	Signal	4	3.2	7.9
Malden			32640	5770	Signal	4	3.3	8.2
Industrial			29740	4050	Signal	4	2.6	6.5
EC Row 1			25300	5330	Ramp Term	3	0.1	0.6
EC Row 2			28320	420	Ramp Term	3	0.0	0.1
Total							*18.4*	*46.1*

HURON CHURCH ROAD			ADT_{N}	ADT_{S}	MODEL	L (KM)	F&I	PDO
EC Row 2	Spring Garden		20100	24200	Arterial	0.39	0.6	2.1
Spring Garden	Grand Marais		18600	23800	Arterial	0.54	0.8	2.7
Grand Marais	Pulford		17800	22200	Arterial	0.55	0.7	2.7
Pulford	Todd/Cabana		18000	22500	Arterial	0.75	1.0	3.7
Todd/Cabana	Huron Church Line		17700	18800	Arterial	0.21	0.3	0.9
Huron Church Line	St. Clair College		9000	12500	Arterial	1.28	1.0	3.7
St. Clair College	Cousineau		11400	13600	Arterial	0.53	0.5	1.7
Cousineau	Howard		11400	10800	Arterial	1.60	1.3	4.7
Total							*6.1*	*22.2*

HCR INTERSECTIONS			ADT_{HCR}	ADT_{INT}	MODEL	LEGS	F&I	PDO
Spring Garden			32460	6340	Signal	4	3.4	8.4
Labelle			8730	1760	Signal	3	0.9	2.3
Grand Marais			12340	5100	Signal	4	1.1	2.7
Pulford			8750	1890	Signal	3	0.9	2.3
Todd/Cabana N			13900	19790	Signal	4	2.6	6.5
Huron Church Line			16830	5280	Signal	3	1.2	3.0
St. Clair College N			9820	2610	Signal	3	1.0	2.5
Cousineau S			10700	9540	Signal	4	1.2	2.9
Howard S			14780	11330	Signal	4	1.8	4.4
401 Ramp at Howard			22970	3300	Ramp Term	4	0.0	0.2
Total							*14.1*	*35.1*

GRAND TOTAL						67	196

ALTERNATIVE 3 - Tunneled facility under Huron Church Road

RAMPS	DIR'N	OFF/ON	RAMP TYPE	ADT	MODEL	L (KM)	F&I	PDO
Highway 3	NB	Off	Flared	9940	Ramp	0.59	0.3	1.3
		On	Flared	7000	Ramp	0.64	0.2	0.9
	SB	Off	Flared	6430	Ramp	0.77	0.2	0.9
		On	Flared	7020	Ramp	0.62	0.2	0.9
St. Clair College	NB	Off	Flared	3200	Ramp	0.41	0.1	0.5
		On	Flared	4660	Ramp	0.41	0.1	0.5
	SB	Off	Flared	5400	Ramp	0.41	0.2	0.7
		On	Flared	5780	Ramp	0.41	0.1	0.6
HCR	NB	Off	Flared	7150	Ramp	0.43	0.2	1.0
	SB	On	Flared	7670	Ramp	0.79	0.2	1.1
Malden	NB	On	Flared	1900	Ramp	0.41	0.1	0.3
	SB	Off	Flared	1100	Ramp	0.49	0.0	0.2
EC Row	SB	Off	Flared	12000	Ramp	0.82	0.4	1.6
Ojibway	NB	Off	Flared	3300	Ramp	0.34	0.1	0.5
		On	Loop	400	Ramp	0.23	0.0	0.1
	SB	Off	Loop	1600	Ramp	0.34	0.1	0.2
		On	Flared	6700	Ramp	0.42	0.2	0.7
EC Row	NB	Off	Flared	1100	Ramp	1.12	0.1	0.2
Total							*2.8*	*12.1*

MAINLINE			ADT	MODEL	L (KM)	F&I	PDO
Plaza	Ojibway		29000	Freeway	0.32	0.4	1.2
Ojibway	EC Row On Ramp		37000	Freeway	0.77	1.5	4.2
EC Row On Ramp	Malden		25000	Freeway	0.42	0.5	1.3
Malden	HCR		19800	Freeway	1.72	1.4	3.9
HCR	St. Clair College		34620	Freeway	2.98	5.3	14.9
St. Clair College	Highway 3		33540	Freeway	3.07	5.2	14.7
Total						*14.3*	*40.3*

HURON CHURCH ROAD			ADT	MODEL	L (KM)	F&I	PDO
College	Girardot		27140	Arterial	0.45	0.8	2.8
Girardot	Tecumseh		23800	Arterial	0.57	0.9	3.2
Tecumseh	Dorchester		29360	Arterial	0.29	0.7	2.8
Dorchester	Prince/Totten		30600	Arterial	0.24	0.6	2.5
Prince/Totten	Malden		34940	Arterial	0.38	0.8	2.9
Malden	Industrial		27810	Arterial	0.90	1.6	5.7
Industrial	EC Row1		31830	Arterial	0.40	0.8	2.9
EC Row 1	EC Row 2		33850	Arterial	0.30	0.6	2.3
Total						*6.8*	*25.1*

HCR INTERSECTIONS			ADT$_{HCR}$	ADT$_{INT}$	MODEL	LEGS	F&I	PDO
College			23750	5730	Signal	4	2.3	5.7
Girardot			24830	2050	Signal	4	1.7	4.1
Tecumseh			27630	8300	Signal	4	3.1	7.8
Dorchester			29960	1870	Signal	4	2.0	4.9
Prince/Totten			33040	4120	Signal	4	2.9	7.3
Malden			31480	4760	Signal	4	2.9	7.3
Industrial			29620	3840	Signal	4	2.5	6.3
EC Row 1			26270	6270	Ramp Term	3	0.1	0.7
EC Row 2			26990	920	Ramp Term	3	0.0	0.2
Total							*17.7*	*44.3*

HURON CHURCH ROAD			ADT$_{N}$	ADT$_{S}$	MODEL	L (KM)	F&I	PDO
EC Row 2	Labelle		20100	24200	Arterial	0.39	0.6	2.1
Labelle	Grand Marais		18600	23800	Arterial	0.54	0.8	2.7
Grand Marais	Pulford		17800	22200	Arterial	0.55	0.7	2.7
Pulford	Todd/Cabana		18000	22500	Arterial	0.75	1.0	3.7
Todd/Cabana	Huron Church Line		17700	18800	Arterial	0.21	0.3	0.9
Huron Church Line	St. Clair College		9000	12500	Arterial	1.28	1.0	3.7
St. Clair College	Cousineau		11400	13600	Arterial	0.53	0.5	1.7
Cousineau	Howard		11400	10800	Arterial	1.60	1.3	4.7
Total							*6.1*	*22.2*

HCR INTERSECTIONS			ADT$_{HCR}$	ADT$_{INT}$	MODEL	LEGS	F&I	PDO
Labelle			33810	5470	Signal	4	3.4	8.3
Grand Marais			17410	5200	Signal	4	1.6	3.9
Pulford			10210	940	Signal	3	0.9	2.1
Todd/Cabana			17650	15170	Signal	4	2.4	5.9
Huron Church Line at Todd			13990	6170	Signal	3	1.3	3.1
St. Clair College			19470	2680	Signal	3	1.1	2.7
Cousineau			9660	11930	Signal	4	1.3	3.2
Howard N			9740	11240	Signal	4	1.2	3.0
Howard S			2670	19210	Signal	4	1.4	3.4
Total							*14.4*	*35.8*

GRAND TOTAL						62	180

ALTERNATIVE – Parkway Alternative (Version 5.3)

RAMPS	DIR'N	OFF/ON	RAMP TYPE	ADT	MODEL	L (KM)	F&I	PDO
Highway 3	NB	Off	Flared	5800	Ramp	0.53	0.2	0.8
	NB	On	Loop	6500	Ramp	0.29	0.1	0.5
Future Laurier	NB	Off	Flared	4900	Ramp	0.57	0.2	0.7
	SB	On	Flared	3900	Ramp	0.51	0.1	0.5
Cousineau	SB	On	Flared	4100	Ramp	0.365	0.1	0.4
Highway 3	SB	Off	Flared	6300	Ramp	0.44	0.2	0.9
Cousineau	NB	On	Flared	500	Ramp	0.542	0.0	0.1
Huron Church Line	NB	Off	Flared	3900	Ramp	0.39	0.1	0.6
Cabana	NB	On	Flared	8900	Ramp	0.44	0.2	0.9
	SB	Off	Flared	7300	Ramp	0.325	0.2	1.0
	SB	On	Loop	2840	Ramp	0.221	0.1	0.3
St. Clair College	SB	Off	Flared	4000	Ramp	0.297	0.1	0.6
	SB	On	Flared	1200	Ramp	0.275	0.0	0.2
Labelle	NB	Off	Flared	14300	Ramp	0.391	0.4	1.8
	SB	On	Flared	14400	Ramp	0.362	0.3	1.2
EC Row	SB	Off	Flared	13250	Ramp	0.751	0.4	1.8
Ojibway	NB	Off	Flared	1200	Ramp	0.307	0.0	0.2
	NB	On	Loop	700	Ramp	0.198	0.0	0.1
	SB	Off	Loop	2400	Ramp	0.323	0.1	0.3
	SB	On	Flared	9800	Ramp	0.41	0.2	0.9
EC Row	NB	On	Flared	1450	Ramp	1.146	0.1	0.4
Total							*3.0*	*12.3*

MAINLINE			ADT	MODEL	L (KM)	F&I	PDO
Plaza	Ojibway		25500	Freeway	0.32	0.4	1.0
Ojibway	Grand Marais		18050	Freeway	3.50	2.5	7.0
Grand Marais	Cabana		46750	Freeway	1.70	4.6	13.1
Cabana	Highway 3		31650	Freeway	3.75	5.9	16.6
Sub-total						*13.3*	*37.6*

HURON CHURCH ROAD			ADT	MODEL	L (KM)	F&I	PDO
College	Girardot		33710	Arterial	0.45	0.9	3.4
Girardot	Tecumseh		30590	Arterial	0.57	1.1	3.9
Tecumseh	Dorchester		35820	Arterial	0.29	0.8	3.3
Dorchester	Prince/Totten		36000	Arterial	0.24	0.7	2.9
Prince/Totten	Malden		40720	Arterial	0.38	0.9	3.3
Malden	Industrial		34160	Arterial	0.90	1.9	6.8
Industrial	EC Row1		37670	Arterial	0.40	0.9	3.3
EC Row 1	EC Row 2		36270	Arterial	0.30	0.7	2.4
Total						*7.9*	*29.3*

HCR INTERSECTIONS			ADT$_{HCR}$	ADT$_{INT}$	MODEL	LEGS	F&I	PDO
College			30680	5680	Signal	4	3.1	7.6
Girardot			32040	2040	Signal	4	2.2	5.4
Tecumseh			34160	8150	Signal	4	3.9	9.8
Dorchester			35430	1870	Signal	4	2.4	5.9
Prince/Totten			38270	4940	Signal	4	3.7	9.2
Malden			37230	5530	Signal	4	3.8	9.3
Industrial			35470	5280	Signal	4	3.5	8.7
EC Row 1			30630	4240	Ramp Term	3	0.1	0.5
EC Row 2			28340	950	Ramp Term	3	0.0	0.2
Total							*22.7*	*56.7*

HURON CHURCH ROAD		ADT$_N$	ADT$_S$	MODEL	L (KM)	F&I	PDO
EC Row 2	Labelle (NBND)	18760	19700	Arterial	0.39	0.5	1.7
EC Row 2	Labelle (SBND)	18370	18400	Arterial	0.41	0.5	1.7
Labelle	Grand Marais (NBND)	17700	3400	Arterial	0.54	0.4	1.4
Labelle	Grand Marais (SBND)	18000	3600	Arterial	0.62	0.5	1.6
Grand Marais (NBND)	Pulford	5400	5400	Arterial	0.55	0.2	0.9
Pulford	Todd/Cabana	6100	14900	Arterial	0.75	0.6	2.1
Todd/Cabana	Huron Church Line	18850	18750	Arterial	0.21	0.3	1.0
Huron Church Line	St. Clair College (NBND)	8400	4500	Arterial	1.31	0.7	2.3
St. Clair College (NBND)	St. Clair College (SBND)	3450	6250	Arterial	1.31	0.5	1.8
St. Clair College (NBND)	Cousineau	12020	12020	Arterial	0.53	0.5	1.7
Cousineau	Howard	11580	8250	Arterial	1.80	1.3	4.8
Total						*6.1*	*21.0*

HCR INTERSECTIONS		ADT_{HCR}	ADT_{INT}	MODEL	LEGS	F&I	PDO
Labelle (N)		17700	4400	Signal	4	1.5	3.8
Labelle (S)		18600	2900	Signal	4	1.4	3.4
Grand Marais		6800	3100	Signal	4	0.5	1.1
Pulford		5400	1900	Unsig	3	0.1	0.2
Todd/Cabana		13200	20350	Signal	4	2.7	6.6
Ramp at Todd/Cabana		16700	7300	Ramp Term	3	0.1	0.6
Huron Church Line		16950	3900	Signal	3	1.2	2.9
St. Clair College		11510	2610	Signal	3	1.0	2.5
Cousineau		12420	9540	Signal	4	1.4	3.4
Howard		10200	11000	Signal	4	1.2	3.0
Total						*11.0*	*27.4*

GRAND TOTAL						64	184