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30 Forensic Engineering

Vancouver | (604) 674-1100
Calgary | (403) 208-4545
Toronto | (416) 368-1700
Ottawa | (613) 903-6900

30fe.com

RED HILL VALLEY PARKWAY INQUIRY
RESPONSE REPORT FOR HIGHWAY DESIGN

Location:	Lincoln Alexander Parkway/Red Hill Valley Parkway, Hamilton, ON
Your File:	51555
Our File:	220488SLB

Prepared for:

Lenczner Slaght LLP
130 Adelaide Street West, Suite 2600
Toronto, ON
M5H 3P5

Participating Consultants:

Dewan Karim, M.A.Sc., MITE, P.Eng., PTOE

The above signature has been electronically applied by Pat Reddick with the express written permission of Dewan Karim.

February 3, 2023

TABLE OF CONTENTS

1.0 SUMMARY

30 Forensic Engineering has been engaged by Lenczner Slaght LLP as an independent Traffic Safety Expert to respond to the report submitted to the Red Hill Valley Parkway Judicial Inquiry by the True North Safety Group, dated November 1, 2022 (the 'TNS report'). A summary of our findings follows.

Based on our review of the initial planning and design documents of the Red Hill Valley Parkway ('RHVP') from 1982 until 2006, we conclude that these documents clearly stated their geometric design assumptions and other design decisions per general professional practices and procedures for planning and designing new urban highway. These documents were later approved by provincial and local decision-making authorities.

Major planning and design decisions were selected or modified (such as the design speed of 100 km/h, interchange spacing, and highway alignment) in the RHVP planning and design documents to reflect the environmental constraints, land-use, and local urban contexts. These decisions followed the industry process of context-oriented use of geometric design guidelines and associated design variations to reduce the impact of a new highway on the environment and surrounding living areas.

The initial design speed of 100 km/h met the recommendations in the MTO design guide and TAC guideline when the RHVP design documents were produced. Per the MTO, a change in design speed does not significantly alter common geometric features, and other directly impacted features could change depending on the scale of design of speed changes. The TNS report did not provide any analytical evidence, substantive safety analysis, or human factors assessment in support of its conclusion that there were "*significant disparities*" in CIMA making recommendations using a different design speed (the 110 km/h design speed used on provincial highways) than the selected RHVP design speed of 100 km/h.

Interchange spacing shorter than what the MTO design guide recommended was decided at a few locations due to the existing road network, adjacent land-use, and other natural or built environment constraints. Flexibility regarding this design decision was allowed in the MTO design guide. This is not unique to the RHVP. Based on the interchange spacings of other comparable highways in Ontario, we conclude that other comparable urban highways also had interchange spacings shorter than what was recommended by the MTO. An accurate quantification of the safety impact of different interchange spacing decisions was not available per the safety manual except at weaving areas, and the design of this area on the RHVP roughly aligned with the MTO design guide. The TNS report did not provide any analysis or statistical models or human factors assessments in support of its conclusions that shorter interchange spacing would lead to violations of motorist expectations.

We disagree with the TNS report's conclusions regarding expectancy violations from a design speed and interchange spacing perspective as the report relied only on a partial statement of MTO recommendations without considering local constraints. The TNS report did not refer to MTO guidance for constrained urban areas, contained no discussions of the consequences of a longer interchange distance or the impracticality of altering local road networks, and only considered a nominal safety perspective, which is not always correct regarding the safety outcome of selecting certain geometric features. Similarly, the TNS report did not refer to local constraints for selecting a design speed and the necessity of CIMA using a design speed for its speed analysis to make recommendations. The TNS report did not analyze weaving sections, did not provide a safety performance analysis for different design speeds, and did not present the required human factors assessment or substantive safety modelling to make major conclusions regarding driver expectancy violations.

We disagree with the TNS report's conclusions that the proportion of major collision types were significantly changed over a 12 year period or before and after any specific year. Our historical trend analysis indicated no major anomaly or decrement in two major collision types over a 12 year period.

We disagree with the TNS report's conclusions that wet road surface related collisions were significantly lower after the 2019 resurfacing. There was insufficient collision data in the TNS report's high-level analysis (only six months before the Covid-19 pandemic and unreliable data during the pandemic) considered after resurfacing. In addition, the TNS report did not perform the recommended process of before-and-after safety assessment as per the Highway Safety Manual.

Based on collision rate comparisons provided to 30FE, the RHVP does not appear to perform significantly differently when compared to other highways or expressways in urban areas in Ontario with respect to safety performance, and it roughly aligns with the City's initial collision rate target for uninterrupted urban highways.

2.0 INTRODUCTION

2.1 Engagement

30 Forensic Engineering has been engaged by Lenczner Slaght LLP as an independent Traffic Safety Expert to respond to the report submitted to the Red Hill Valley Parkway Judicial Inquiry by the True North Safety Group, dated November 1, 2022 (the 'TNS report').

2.2 Duty of Experts

This report has been prepared by Mr. Dewan Karim. A summary of the author's pertinent employment and educational experience is provided within the Curriculum Vitae included as Appendix A.

The instructions provided have been repeated in the preceding section. The findings reached in this report, and the reasons and basis for these findings, including any assumptions made or research performed, will be discussed in the sections to follow. The author acknowledges his duty to provide evidence that is objective, non-partisan, and related to areas within his expertise, in order to assist with an understanding of the matters at hand.

3.0 BACKGROUND

3.1 Scope of the Report

This report addresses certain highway design and safety issues identified in the TNS report with respect to the Red Hill Valley Parkway Inquiry. The following issues were approved by Justice Herman Wilton-Siegel, Commissioner:

- Comment on the intended use of geometric design guidelines;
- Comment on the alleged expectancy violations with respect to design speed and interchange spacing asserted by Mr. Brownlee;
- Comment on the standard methodology used to interpret collision data and address the statistical conclusions regarding collision trends drawn by Mr. Brownlee; and
- Comment on Mr. Brownlee's opinion on the ranking of potential contributory causes to wet road crashes as raised in Mr. David Boghosian's legal analysis.

3.2 Approach to Highway Design, and Safety Analysis

The analysis and results presented in this report are based on the provided documents and generally accepted professional standards, guidelines, and best practices used in highway design and the maintenance of highways in Ontario.

We have not been asked to perform a full highway design review of the RHVP including initial design and build documents. However, the RHVP documents were reviewed at a high level to gain an understanding of the overall history and process of the initial highway design and building activities. A list of the documents provided for overall review is provided in Appendix B.

We have reviewed a series of documents produced by CIMA, which was retained by the City of Hamilton (the 'City') on various occasions roughly over the 2010-2020 time period. These reports informed our background understanding, including the RHVP's safety and operations after it was built in 2007.

Finally, we have performed a limited independent analysis of safety and geometric highway design features as part of this assessment of the RHVP. We also performed an in-vehicle trip on the RHVP on July 19, 2022, to gain a general understanding of the current highway status and operational conditions. In addition, we used aerial view and mapping software (ArcGIS) for spatial analysis and illustration of our analysis findings. However, this approach is limited, and it is not possible to perform a fully detailed geometric evaluation based on these reviews.

3.3 Brief Outline of Initial RHVP Planning and Design Process

The planning and design of the RHVP went through several processes from 1982 until its completion in 2007. A summary of key highlights from the planning and design processes, which underlay the assumptions and background information for this report, is provided in Appendix C. Our overall review included the following:

- Review of the 1982 environmental review to understand planning objectives, challenges, constraints, key high-level design criteria, and key engineering decisions that went into building a new urban highway in the City of Hamilton;
- Review of the 1990 preliminary design document to understand the source of geometric design guidelines or standards and key design decisions such as interchange spacings;
- Review of the 2003 preliminary design document to understand the impact assessment and modifications to the initial 1990 design decisions; and
- Review of the 2006 preliminary design document to understand the final design criteria that were proposed or selected for design and the building of the RHVP during construction.

3.4 Intended Use of Design Guidelines

The purpose of geometric design guidelines and their appropriate use typically varies under context-oriented conditions. This section provides an overall highlight of this issue to clarify the intended use of geometric design guidelines and establish a base background context of their intended and appropriate use and different approaches to traffic safety. This is explained in five stages:

1) General use and process of geometric design guidelines to explain how these documents are recommended to be used by industry professionals;
2) Design decisions including exceptions or deviations (i.e., when and how exceptions are practiced and the process of documentation);
3) The difference between standards and guidelines;
4) Recent introductions of highway safety guidelines or documents to provide proper assessment tools for safety practitioners to identify mitigation measures for existing or future highway facilities; and
5) Two different concepts of traffic safety: nominal safety (compliance or noncompliance with geometric design guidelines) and substantive safety, which requires a proper scientific safety assessment of highway facilities, validates the findings, and identifies mitigation measures to address current or potential future safety performance.

3.4.1 General Use of Geometric Design Guidelines

Geometric design generally refers to the dimensions and arrangements of the visible features of a roadway or highway.[1] This includes pavement dimensions such as lane, shoulder, and roadside widths, horizontal and vertical alignment, cross and longitudinal slopes, channelization of traffic flow, various types of intersections, and other features that can significantly impact the operations, safety, and capacity of the roadway or highway network.

Among industry professionals, the geometric design of the roadway or highway should be consistent with the intended functional classification of the highway and should fit the natural or

[1] What is Geometric Design, Institute of Transportation Engineers.

built environment, land-use, or other contexts or characteristics and the needs of all of its users. Note that geometric design criteria in these guidelines assume a series of design controls[2] (i.e., expected typical behaviours of various roads users and vehicles that display a range of typical characteristics and limitations). Extreme conditions (such as extreme weather) or unexpected or erroneous user behaviour are not typically included in the design controls.

Industry professionals along with research and standards-setting organizations or institutions developed various geometric design practice handbooks or guidelines over the 20th century. These industry documents are based on design vehicle dimensions and performance, expected driver behaviour and performance, and contemporary technologies.[3] These documents provide an opportunity to develop consistent professional practices instead of arbitrary assumptions or approaches by individual or local areas or regions.

When assumptions about design controls, societal, environmental, or technological changes occur over time, the geometric design guidelines accommodate changes in design practices. This change of approach is also intended to provide greater flexibility to the designer in addressing issues of concern related to constrained, unusual, or sensitive design environments. Professional practitioners are required to apply engineering judgment to justify various changes or deviations, which should be properly investigated and documented. If old roadways or highways no longer comply with new practices or changes, it does not imply those facilities are necessarily inadequate. If constraints or unusual situations are faced by the engineers or practitioners, reasonable deviations are allowed to be made in roadway and highway projects. The context of roadways or changing community needs may require engineers to apply geometric designs that are similar to the prescribed recommendations in industry documents, but which could result in a roadway appearance different than other roadways due to different environmental or land-use content.

3.4.2 Process of Design Decision Exceptions or Design Deviations

When a specific project, or the anticipated impact of a project, can result in negative impacts to a community, natural, or human environment, design exceptions or deviations are encouraged by the industry's professional documents. These decisions are made using engineering judgment, technical references, and calculations[4] to determine the primary design for specific projects or conditions.

For instance, the Transportation Association of Canada's Geometric Design Guide for Canadian Roads (1999 or 2017) (the 'TAC guideline') and the MTO's Geometric Design Standards for Ontario Highways (1985) (the 'MTO design guide') support design flexibility and a context-sensitive approach which considers the full range of project needs and the impacts to the community and natural and human environment. It reads that "*How they* [the guidelines] *are*

[2] In general, typical design controls are attributes, values, or qualities that influence discrete geometric element dimensions or considerations. Geometric design criteria are dimensions and values that meet design control needs, such as curve radius, cross section, and merge lengths.
[3] Geometric Design Guide for Canadian Roads. (1999 or 2017). Transportation Association of Canada ('TAC').
[4] Geometric Design Guide for Canadian Roads – Section 1.1.1. (1999). TAC.

applied depends on agency policies, transportation characteristics, such as vehicle and driver populations, and on such site-specific features as terrain and adjacent development."[5]

The geometric design guidelines provide a range of acceptable values for highway design features and these documents support the use of this flexibility to achieve a design which best suits the desires of the community while also satisfying the purpose for the project and needs of its users. In addition, the guidelines acknowledge that design decisions, including exceptions, are a useful tool that may be employed to achieve a balance of project needs and community values. Local roadway or highway authorities must evaluate, approve, and document design decisions or exceptions. Factors that influence design decisions include:[6]

1) "*Mobility*
2) *Environmental impacts*
3) *Safety*
4) *Capital costs*
5) *Aesthetics*
6) *Maintenance costs*
7) *Vehicle operating costs*."

Once the reason for a deviation is documented, the roadway or highway can be built with the selected geometric design features. This does not imply that the future safety performance of the highway is guaranteed to be 'safe.' The TAC guideline (1999) states that "*it is impossible to make a road completely safe, by 'safe' we mean a road on which we can guarantee that there will never be a collision*." A few key geometric design decisions such as a design speed of 100 km/h, which is slightly different than provincial highways, were clearly stated in the City's planning and design RHVP documents (see Appendix C), and appropriate descriptions were provided in all documents. These documents were approved by the Ministry of Environment or Hamilton City Council as a collective decision-making process (see Appendix C).

3.4.3 Distinction Between Standards and Guidelines

In general, compliance with standards is more restrictive, whereas guidelines are recommendations that may or may not be met under different contexts or circumstances.

The distinction between standards and guidelines often leads to the misperception that deviation from prescribed guidelines is the same as deviation from standards. Standards are set by approved standards setting organizations and are typically of a higher authority, limited in application. Standards are typically developed for very precise applications of design elements such as rail gage, the height of guard rails or bridge railings, and larger exceptions or where certain deviations that can lead to significant safety consequences. As stated in the TAC guideline (2017/1999), "*Historically, road design 'standards' usually based on laws of physics or*

[5] Geometric Design Guide for Canadian Roads – Section 1.1.1.2 The Use of Guidelines and Standards. (1999). TAC.
[6] Geometric Design Guide for Canadian Roads – Section 1.1.2.3 Design Decisions. (1999). TAC.

empirical data have been provided to designers. These 'standards' were not intended to be rigid, or to be applied uniformly in all cases."[7]

Design guidelines can be developed by a group from within the professional community without approved standards setting organizations. Roadway or highway design guidelines can be found in various forms; for example, journal articles, technical reports, general handbooks, and industry-specific or topic-general documents. The guidelines allow greater flexibility regarding the range of design elements that can be used for specific projects or local contexts.

3.4.4 New Safety Manual with a Scientific Approach to Safety Assessment

Road designers are not usually required to examine road safety issues related to geometric design. Before the mid-1990s, a nominal safety approach assumed that a "*road designed to meet minimum standards would be 'safe'*."[8] This is an incorrect road safety assumption. Although geometric design guidelines were available to practitioners for the last six decades, the evaluation of safety performance of existing or future expected projects following the implementation of any countermeasures was not available to industry professionals. Limited safety assessment tools were available to industry practitioners before the mid-1990s; however, there were no comprehensive guidelines that maintained the consistency of safety assessment tools and processes until 2009, aside from the new version of the TAC guideline in 2017.

The safety assessment practices began to change after major guidelines were published. For instance, the Highway Safety Manual (HSM)[9] is a major safety manual[10] that provides safety knowledge and tools in a useful form to facilitate improved decision-making based on the safety performance of facilities in roadway or highways. The guideline is now widely accepted and used by Canadian, U.S., and other jurisdictional practitioners.[11] In summary, the HSM is a tool that applies an evidence-based technical approach to safety and a quantitative process of safety impacts of specific implementations, in contrast to reliance on safety perceptions or an individual's assumption that may or may not be correct.

The HSM begins to fill the safety knowledge gap, providing transportation professionals with updated and current knowledge, techniques, and methodologies to estimate future crash frequency and severity. It also identifies and evaluates options to reduce crash frequency and severity if a roadway or highway is experiencing collisions at a certain location or at certain types of facilities. Generally, there are four basic steps for the substantive safety assessment 1) Collect extensive data, 2) Develop empirical equations for associating collision rates and a specific set of geometric features, 3) Calibrate the model using local data, and 4) Ensure the results are statistically significant to identify the measurable impact of geometric design features and recommend countermeasures.

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[7] Geometric Design Guide for Canadian Roads – Section 1.1.2 – The Use of Standards and Guidelines. (2017). TAC. or Geometric Design Guide for Canadian Roads – Section 1.1.1.2 – The Use of Standards and Guidelines. (1999). TAC.
[8] Geometric Design Guide for Canadian Roads – Section 1.1.2 – The Use of Standards and Guidelines. (2017). TAC.
[9] Highway Safety Manual. (2009). Federal Highway Administration.
[10] As stated in the HSM, "*prior to the initial edition of the HSM, transportation professionals did not have a single national resource for quantitative information about crash analysis and evaluation*."
[11] Although the HSM is mainly a federal U.S. funded initiative, Canadian professionals contributed toward the building of this new safety knowledge.

Other U.S. federal safety agencies such as NCHRP,[12] TCRP,[13] IIHS,[14] AASHTO,[15] NACTO,[16] and TAC and ITE[17] in Canada produced a series of safety manuals and guidelines including best practice documents during the last 20 years.

3.4.5 Nominal Safety vs. Substantive Safety

Since the inception of safety knowledge for transportation professionals, it became apparent that the difference between compliance with geometric guidelines or standards and actual safety outcomes was not well known among industry professionals. To reduce this knowledge gap and differentiate between two concepts, 'Nominal Safety' vs. 'Substantive Safety' concepts were introduced by roadway or highway industry organizations such as the U.S. federal highway administration (FHWA).[18] Nominal safety is defined as "*a consideration of whether a roadway, design alternative, or design element meets minimum design criteria*".[19] In contrast, "*Substantive safety is defined as the actual long term or expected safety performance of a roadway. This would be determined by its crash experience measured over a long enough time period to provide a high level of confidence that the observed crash experience is a true representation of the expected safety characteristics of that location or highway.*"[20]

Since the definition of safety performance varies from person to person and creates a common source of confusion as to what is safe or unsafe, it is important to understand that the substantive or long-term safety performance of a roadway does not always directly correspond to its level of nominal safety, even though all geometric design criteria were met.[21] Even a roadway that is nominally safe (i.e., all design elements meet design criteria) is not automatically substantively safe or vice versa. Despite complying with geometric design guidelines or standards, specific sections of the facilities of a highway could still experience higher crash volumes due to various local constraints or conditions that were not included in the typical condition or geometric design details developed in industry documents.

To appropriately monitor highway safety conditions, industry professionals developed continuous monitoring through data collection, maintenance, and inspection processes. Typically, a roadway or highway authority performs major safety reviews every five years and publishes or analyzes annual crash experiences. For instance, the City publishes annual safety reports for all major roadways in Hamilton, including special safety data for the RHVP. In addition, the City also hired CIMA to review the safety conditions of the RHVP. Note that CIMA applied a substantive safety assessment for a few highway safety topics. In contrast, for this Inquiry, the TNS report relied solely on nominal safety and did not perform any comprehensive safety analysis in support of its conclusions.

[12] The National Cooperative Highway Research Program (NCHRP).
[13] The Transit Cooperative Research Program (TCRP).
[14] The Insurance Institute for Highway Safety (IIHS).
[15] The American Association of State Highway and Transportation Officials (AASHTO).
[16] National Association of City Transportation Officials (NACTO).
[17] Institute of Transportation Engineers (ITE).
[18] Nominal and Substantive Safety, FHWA.
[19] Nominal Safety, FHWA.
[20] Substantive Safety, FHWA.
[21] Milton, J.C. (2012). "The Highway Safety Manual": Improving Methods and Results. *TR News*, (282).

4.0 ANALYSIS AND REVIEW OF TNS REPORT

4.1 Study Area, Roadway Function, and Speed

The RHVP was constructed in 2007. The relevant design criteria at the time of construction was in the MTO design guide.

According to the City's Official Plan, the RHVP was classified as a 'Parkway.' The RHVP connects major arterial, minor arterial, and collector roads to provincial highways. The land use surrounding the RHVP is a mixture of 'neighbourhoods' and 'major open spaces' as per the Official Plan.[22] The surrounding land use in the City's Official Plan is designated as "*urban*."[23]

The speed limit of the RHVP was 90 km/h, and effective May 17, 2021, the RHVP speed limit was changed to 80 km/h.[24]

4.2 Design Speed

4.2.1 Recommended Process of Selecting Design Speed

When a highway is in the planning stages and design begins, industry professionals select a design speed for geometric design considerations. Several highway planning and design authorities provide guidance to help professionals select an appropriate design speed. For instance, the MTO design guide defines design speed as "*a speed used for the design and corrections of the physical features of a highway that influence vehicle operations*."[25]

The selected design speed is the first stage of the geometric design process and establishes the range of design values for many of the other geometric elements of the highway (design speeds vary appreciably in terms of their design features such as curvature, superelevation, and sight distance). The selection of a design speed of a specific roadway or highway facility recognizes a range of site-specific topography conditions, natural environmental constraints, and land-use or built environment contexts that designers face, as well as the type of highway itself. The adopted design speed criteria allow a great deal of design flexibility by providing ranges of values for a design speed. For instance per the MTO design guide, the design speed of an urban freeway on level or rolling terrain in a rural area is 100 to 120 km/h, but in urban areas, the design speed of a freeway could start from 80 km/h and could be higher, such as 120 km/h, if suitable conditions exist.[26] Typical design speed ranges are provided in Table 1. Depending on the design speed selected, relevant highway features are determined to maintain a balanced design. The design speed selected by the roadway authority should be high enough so that an appropriate regulatory speed limit will be less than or equal to it. Typically, in Ontario, design speeds are 10-20 km/h higher than the posted speed limit.[27]

[22] Hamilton Official Plan, Appendix 11, Functional Road Classification Map. City of Hamilton.
[23] Urban Hamilton Official Plan, Schedule E, City of Hamilton.
[24] CBC News. (2021). City will drop speed limit on Red Hill Valley Parkway starting Monday. https://www.cbc.ca/news/canada/hamilton/speed-limit-reduction-on-red-hill-valley-parkway-begins-monday-1.6025779
[25] MTO. (1985). *Geometric Design Standards for Ontario Highways*. Section A.5.6.2 – Design Speed.
[26] MTO. (1985). *Geometric Design Standards for Ontario Highways.* Section A.5.9.5 – Urban Freeways.
[27] MTO. (1985). *Geometric Design Standards for Ontario Highways.* Section A.5.7 – Design Speed Selection.

Table 1: Summary of Design Speed for Urban Highways.

Geometric Design Guidelines / RHVP Documents	Recommended Design Speed km/h	Comments
MTO Design Guidelines	80 – 120[28]	For Urban Freeways with an A.A.D.T of more than 75,000
TAC Design Guidelines (1999)	80 – 120[29]	For Urban Freeways with traffic volume >20,000 vehicle per day
1982 EA Report – (RHVP)	100[30]	For "*Divided Urban Freeway*"
1990 Preliminary Design (RHVP)	100[31]	According to Highway Classification "*UFD 100*"

4.2.2 Review of RHVP Design Speed

For the RHVP, a posted speed limit of 90 km/h would be appropriate for a design speed of 100 km/h to 110 km/h. When the RHVP was first planned in 1982, an environmental assessment was completed (the '1982 EA report'), and a design speed of 100 km/h was selected (Table 1). This design speed was selected given the urban conditions, designated environmental constraints, and associated construction difficulties including cost considerations.

The RHVP design speed decision, including variance (reduction in design speed relative to provincial highways), was documented in the 1982 EA report and subsequent design reports (see Appendix C) following industry processes and engineering practices described in Section 3.4 above. This design decision aligns with the general principles recommended in the MTO design guide: "*Desirable design values should be used when feasible, but in view of the numerous constraints often encountered, acceptable values are recognized and used.*"[32]

Choosing a higher design speed can result in greater impacts on the environment and larger design requirements to be accommodated. The driving experience and expectancy difference under different design speeds depends on the degree of relevance of different types of geometric design factors. Per the MTO design guide (Section A.5.6.2), different geometric design features have different impacts when design speeds are changed:

- Some common features such as pavement width, lane width, shoulders, and clearances to walls and rails are 'less directly' impacted by design speed and instead affect vehicle operating speed.[33] Based on an overall review of these elements, between design

[28] MTO. (1985). *Geometric Design Standards for Ontario Highways*. Chapter A, Section A.5.7 and Section A.5.9.5.
[29] Geometric Design Guide for Canadian Roads – Chapter 1.3, Section 1.3.4, Table 1.3.4.2. (1999). TAC.
[30] Environmental Assessment Submission. (1982). Section 6.1.1, Table 6.1.
[31] Preliminary Design Report. (January 31, 1990). Appendix A, Page 1.
[32] MTO. (1985). *Geometric Design Standards for Ontario Highways*. Section A.5.6.2 – Design Speed.
[33] Per the TAC guideline, "*Operating speed refers to the 85th percentile speed of vehicles at a time when traffic volumes are low, and drivers free to choose the speed as which they travel.*"

speeds of 100 and 110 km/h, there are minor or no differences between highway geometry and associated driving conditions.[34]

- Some other features that are 'directly related' to design speed such as curvature, superelevation, and sight distances vary appreciably with significant changes of design speeds.[35] A substantive safety assessment for different design speeds should be performed to quantify the different safety outcomes and whether they are statistically significant.
- A maximum design speed is selected when favourable highway conditions exist. The MTO defined favourable highway conditions as "*(a) good weather – clear, bright, dry (b) low traffic volumes.*" Note that the minimum design speed (Table 1) for urban areas is lower than in rural areas to reflect this key design principle.
- Based on these guidelines, we conclude that a design speed of 100 km/h aligns with the MTO guidance for considering constraints, urban conditions, and other natural and built environments that exist alongside the RHVP.

4.2.3 Response to TNS Conclusions on Design Speed

Regarding the design speed, the TNS report concluded:

> *"Had CIMA been advised of the actual design speed of 100 km/h on the RHVP, they would have identified the significant disparities between the posted, design, and operating speeds, and potentially adjusted their assessment scope, assumptions, or range and/ or immediacy of potential remedial actions."*

We disagree with the conclusions regarding *"significant disparities"*:

- As stated earlier, for some geometric design features less directly related to design speed, measurements would be the same or similar for small changes in design speed (such as a 100 vs. 110 km/h design speed) and expected outcomes would be similar. Changes of safety performance would be noticeable for geometric design features directly related to design speed. But the changes in safety outcomes and related recommendations need to be verified to determine whether a small change of design resulted in significant changes in collision experience. The TNS report did not perform this substantive safety assessment in support of the above conclusions.
- In addition, a lower design speed reflects frequent curvatures, environmental constraints, and difficult terrain on the RHVP's route as recommended in the TAC guideline based on scientific research findings (for instance, this is noted in Section 3.2.2.2, Human Factors Consideration on Curves in the 2017 edition of the TAC guideline).
- In general, a safety assessment for existing highway speeds focuses on the posted speed limit and existing operating speed, not the design speed per the HSM.[36] The TNS

[34] For instance, travel lane width is 3.75 metres and median shoulder width is 3.0 metres for both 100 and 110 km/h design speeds as per the MTO design guide.

[35] For instance, stopping sight distance is 185 metres for a design speed of 100 km/h and 215 metres for a design speed of 110 km/h. Similarly, minimum horizontal curvature (circular) is 420 metres for a design speed of 100 km/h (for a superelevation 0.06 and a maximum co-efficient 0.128) and 525 metres for a design speed of 110 km/h.

[36] Per the HSM (2009), "*The following geometric design and traffic control features are used to determine whether the site specific conditions vary from the base conditions and therefore whether an AMF is applicable: Speed category (based*

report did not explain whether design speed was needed for all safety assessments completed by CIMA. If design speed was not required per the HSM, CIMA could still make safety recommendations using its design speed.

- Based on a review of geometric design and safety guidelines, we conclude that CIMA's safety analysis would have predominantly depended on the posted and operating speeds. Design speed is directly related to the 'design' process of a highway and provides a relevant background to understand the existing features of a built highway. For this reason, CIMA's recommendations would not be substantially different since it relied on the existing physical attributes of the RHVP.
- The TNS report did not provide analysis or statistical modelling on substantive safety in support of the conclusion that there would be "*significant disparities*" for different design speeds.
- The decision to lower a posted speed limit or corresponding design speed is typically made to adjust to and inform drivers of constrained conditions and is communicated through signage and pavement markings. Since the City adopted a lower posted and design speed for the RHVP and communicated this via highway signs/markings, we conclude that a lower design speed of 100 km/h for the RHVP was a justified and appropriate decision given the urban and environmental conditions that exist along the urban highway.

4.3 Interchange Spacing

Interchanges are vital components of freeways or expressways that provide reasonable access to adjacent lands and improve mobility for the people living within the catchment areas of an interchange. At the same time, interchanges introduce conflict points in uninterrupted highway operations, particularly regarding operational constraints, safety, and the capacity of the mainline of freeways or expressways.

4.3.1 Definition of Interchange and Its Elements

Interchange spacing related guidelines such as NCHRP report 687[37] define interchange spacing as "*The distance measured between the respective centerlines of freeway cross streets that include ramps to or from that freeway.*" Note that the selection of interchange spacing depends on local land-use designations and local street spacings, particularly in urban areas.

The most critical component of interchange spacing distance is where conflict activity happens, i.e., weaving sections (particularly between subsequent on- and off-ramps), which is typically referred to as ramp spacing as per MTO guideline (Figure 1). This component is defined as "*The distance between the tips of the actual or theoretical convergence of the painted gore stripes (painted tips).*"

on actual traffic speed or posted speed limit)", Part C - Predictive Methods, Chapter 12, section 12.4, page 12, and Step 4 - Determine geometric design features, traffic control features and site characteristics for all sites in the study network.

[37] Ray, B. (2011). *Guidelines for ramp and interchange spacing* (Report 687). Transportation Research Board.

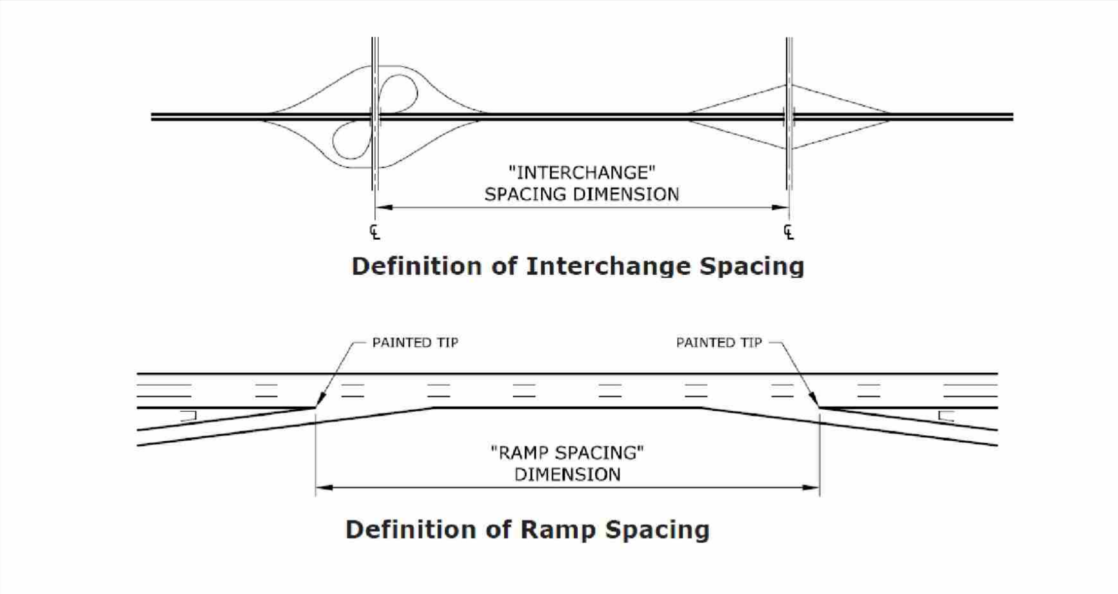

Figure 1: Diagram of the official definitions of interchange spacing and ramp spacing (Source: NCHRP 687, 2011).

4.3.2 Substantive Safety: Interchange Spacing and Safety

In urban areas and other facilities that carry large traffic volumes, the interchanges and associated ramps are located closer together than on provincial or interstate connected highways. The spacing of interchanges on an urban road network can also result in trade offs between providing adequate traffic operational service and access with both safety and operations.

The knowledge of interchange spacing, and its impact on substantive safety were developed in the mid-1990s and mostly in 2009 with the HSM and onwards. This encounters a nominal safety approach that not strictly meeting the recommended interchange spacing would result in an unsafe highway. This is an incorrect assumption. The HSM recommends specific procedures for a substantive safety approach:

- The HSM on the safety impact of interchange spacing: Actual substantive safety impacts of different interchange spacing decisions (i.e., changes in collision experiences due to different interchange spacings) remain unknown. Although evaluation can be done, no definitive safety model or collision modification factors are available to general industry practitioners to quantify the safety impact of interchange spacing. The highway authority document and recent research document[38] states:
  - "*Although there are ways to evaluate these operational benefits quantitatively, to date researchers have not expressed in measurable terms the compromise in safety, or the increase in crashes per mile of freeway*."

[38] Bared, J.G., & Zhang, W. (2007). *Safety Assessment of Interchange Spacing on Urban Freeways* (Publication No.: FHWA-HRT-07-031). Federal Highway Administration.

- In addition, the HSM[39] does not provide any direct estimates of safety impacts as a result of changes in interchange spacing. Note that these documents are widely used by Canadian practitioners.
- However, based on isolated studies[40] have been completed on the substantive safety impact of interchange spacing it was concluded that there is insufficient data, inadequate sample size, and subsequently high difficulty of developing safety models to determine the magnitude of the effect on collision rates (i.e., no definitive conclusions can be made between interchange spacing and collision rate changes).
- Many other critical influencing factors on these crash experiences (such as horizontal and vertical alignments of ramps and freeways within the spacing and at the approaches, ramp lengths, lighting, and similar factors) remain unknown. Therefore, knowledge of interchange spacing's effect on safety outcomes remains very difficult to quantify and therefore makes any major conclusions nearly impossible without further scientific research on this issue.
- Finally, the HSM produced limited estimation processes to assess or address weaving conflicts between on- and off-ramps. Design and safety measures for weaving conflicts are typically paid greater attention since recommended interchange spacing is not always practically achievable.

4.3.3 Recommendations for Interchange Spacing

As indicated earlier, geometric design guidelines provide nominal safety perspectives for the process and selection of interchange and ramp spacing. Note that interchange spacing and associated weaving section recommendations are different for typical provincial or interstate highways compared to more constrained urban areas.

Canadian/Ontario Guidelines

According to the 1985 MTO design guide, the relevant guide at the time of construction for the RHVP, the recommended interchange spacing for urban areas was 2 to 3 km.[41] The guide notes the following with respect to urban freeways (Section F.4.2):

> *"On urban freeways traffic conditions and driver behaviour are different from those of rural freeways, and this influences spacing. Operating speeds tend to be lower, trip lengths shorter, traffic volumes higher, and drivers are accustomed to, and anticipate the need for taking a variety of actions in rapid succession. Interchanges spaced at more than 3 km over a length of urban freeway normally cannot provide the overall capacity to give adequate service to urban development, and closer interchange spacing is called for. If successive interchanges are too close, the operation of the freeway becomes seriously impaired and the freeway loses its capacity to collect and deliver traffic from the crossing arterial roads.*

[39] Section A.2.2.2 - Modify Interchange Spacing.
[40] McGee, H.W., Hughes, W.E., & Daily, K. (1995). *Effect of highway standards on safety, Chapter 4* (Report 374). Transportation Research Board.
[41] MTO. (1985). *Geometric Design Standards for Ontario Highways*. Section F.4.2.

Interchange spacing in urban areas generally ranges from 2 km to 3 km. Interchanges should be located at major arterial roads, forming part of the arterial system of roads for the urban areas and providing, or having the potential to provide, capacity to deliver to and collect from the interchanges.

If arterial roads are spaced closer than 2 km, it is necessary either to omit some of the interchanges in favour of grade separations or adopt some alternative means of combining interchanges to service closely located arterial roads."[42]

Other Guidelines Commonly Used in Canada

The basis of the MTO recommendations were local regulations and the AASHTO Green Book,[43] which has provided a general rule for minimum interchange spacing and values for minimum ramp terminal spacings since 1984. Section 1.1 of NCHRP report 687 also summarizes these recommendations as follows:

> "*Interchanges and their historic rule-of-thumb 'one-mile'* [1.6 km] *spacing in urban areas are ultimately a by product of the traditional spacing of urban street networks. The networks and their grid vary, but it is relatively common to have major streets and roadways set upon a one-mile grid, with minor streets placed uniformly at values of 8 to 10 streets per mile. During the early days of freeway and interchange planning, the one-mile spacing in urban areas was a result of balancing total system travel demand. In major cities, early traffic models and studies showed that interchanges placed one mile apart balanced traffic flow on the arterials. Spacing values greater than one mile resulted in overly congested conditions on those arterials that interchanged with the freeway.*"

Based on our overall review, the research study stated that interchange spacing varies widely from 1 km to 2 km for urban areas.[44] Other manuals such as the Highway Capacity Manual[45] provide analysis procedures for weaving sections and ramp-freeway junctions and MUTCD[46] (or the Canadian CMUTCD) provide guidance on how many advance guide signs should be placed prior to an exit and how far in advance of an exit they should be placed.

4.3.4 Assessment of Interchange Spacing on the RHVP

We performed a high-level interchange analysis for the RHVP. Interchange spacing was measured as per the definition provided in NCHRP report 687.

Based on the above noted criteria, we measured from the centre of the interchange using aerial mapping from Google Earth imagery. Based on our measurements, the segment that falls within the 2 to 3 km spacing that the 1985 MTO design guide recommends is the 'Mud Street

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[42] This section of the MTO design guide includes an example of an alternative means for designing a shorter interchange spacing. Figure 4-1 illustrates that a recommended spacing of 2-3 km can be achieved in a full interchange. Figure 4-2 illustrates how partial interchanges can be used for shorter interchange spacings (i.e., less than 2 km).

[43] American Association of State Highway and Transportation Officials. (2004). A *Policy on Geometric Design of Highways and Streets*. Washington, D.C.

[44] Bared, J.G., & Zhang, W. (2007). *Safety Assessment of Interchange Spacing on Urban Freeways* (Publication No.: FHWA-HRT-07-031). Federal Highway Administration.

[45] Transportation Research Board (2010). *Highway Capacity Manual*. Washington, D.C. Publication anticipated by date of guidelines publication.

[46] Federal Highway Administration. (2009). *Manual on Uniform Traffic Control Devices (MUTCD)*. Washington, D.C.

Interchange to South of Greenhill Avenue' (approximately 2.51 km). The remaining segments are below 2 km and only the interchange spacing in or around King Street fell below 1 km.

The recommended interchange spacing at King Street was not practical due to it being an "*environmentally sensitive area*," providing access on both sides of the highway, and the impracticality of changing the existing roadway spacing between King Street and Queenston Road. The MTO design guide allowed for shorter interchange spacing (Section F.4.2) when it is impractical to achieve the recommended spacing. For instance, the MTO design guide noted that closer interchange spacing may exist to match the context of adjacent land-use, as well as the constraints, configurations of interchanges (an illustrative example is provided in Figure 4-2 for an alternative means of designing a shorter interchange spacing),[47] and spacing of the existing road network. Therefore, shorter interchange spacing could be considered in cases where it is not possible to space interchanges at least 2 km apart.

4.3.5 A Comparison Analysis of Interchange Spacing

Urban areas present unique challenges, as discussed in Section 3.2 on the RHVP background and in this section regarding urban area constraints. Consequently, the RHVP is not unique in terms of the type of roadway in an urban environment. Table 2 outlines a comparison summary of similar proxy sites compared to the RHVP. We used aerial satellite images (such as Google Earth and other online GIS resources) to estimate the interchange spacing. Four other highways were reviewed for their interchange spacing to compare to the RHVP, including:

- Don Valley Parkway in the City of Toronto;
- Highway 403 in the City of Hamilton;
- Highway 406 in the City of St. Catharines; and
- Highway 7/85 in the City of Kitchener.

These highways were reviewed because they have posted speed limits of at least 90 km/h, and they are also in urban or combination land-use areas similar to the RHVP's conditions. The minimum and maximum interchange spacing range is listed in the table, with Highway 7/85 having an interchange spacing with the lowest minimum. The interchange ratio was calculated for each highway to determine the average number of interchanges per kilometre, and we found that the RHVP had the highest number of interchanges per kilometre, closely followed by Highway 7/85. Finally, the average interchange spacing was calculated for each highway. Based on this analysis, Highway 7/85 had the lowest average interchange spacing.

Overall, we can conclude that a mature urban and arterial spacing network existed prior to when these highways were built, and each of the highways have at least one interchange spacing of less than 2 km and an average interchange spacing that is similar to that of the RHVP. This highlights the constraints of having freeways/parkways in an urban area and shows that the RHVP is comparable to other highways in southern Ontario. Rural or very low-density urban/suburban areas (such as Highway 403 or 406) were able to maintain interchange spacings of 2 km or greater due to greater local network spacing and limited constraint conditions.

[47] Note that some of the interchanges on RHVP were partial interchanges and different configurations compared to the relatively less constrained interchanges of the Lincoln Alexander Parkway.

In addition, our cursory review of weaving areas between the on- and off-ramps reveals that most of these ramp spacing distances or weaving sections were close to the MTO minimum recommended distance of 600 metres for ramp spacing (within 90-100 metres).[48] This typically indicates the most critical element of interchange spacing was considered with greater care, and that efforts were made to minimize weaving conflicts.

Table 2: RHVP interchange spacing compared to similar proxy sites.

Highway	From/To	Distance (km)	Interchange Spacing Range (km)	No. of Interchanges	Ratio (Interchange /km)	Average Spacing (km)	Adjacent Urban Conditions
RHVP	Mud Street/ Barton Street	7.17	0.84 - 2.51	6	0.84	1.43	Mostly urban and frequent arterial spacing
Don Valley Parkway	Gardiner Expressway /Eglington Avenue East	9.85	0.44 - 3.05	7	0.71	1.64	Mostly dense urban and frequent arterial spacing
Highway 403 Hamilton	Wilson Street/ Highway 6	15.4	1.1 - 4.7	8	0.52	2.20	Mostly rural areas
Highway 406 St. Catharines	QEW/ Glendale Avenue	9.2	2.3 - 3.9	4	0.43	3.07	Partly rural and low-density urban
Highway 7/85 Kitchener	Homer Watson Boulevard/ King Street North	12.1	0.3 - 2.4	10	0.83	1.34	Mostly urban and frequent arterial spacing

4.3.6 Response to TNS Report on Interchange Spacing

Regarding interchange spacing, the TNS report stated:

> "*The majority of the interchanges on the RHVP were spaced less than specified, with the distance between King Street and Queenston Road interchanges being the least and less than half the minimum value outlined in the 1985 MTO Design Guide for urban freeways*."

[48] Except for the section between Queenston Road and King Street East, which was roughly 415 metres.

We disagree that not achieving the recommended interchange spacing would be an issue given the local constraints adjacent to the RHVP:

- The TNS report only relied on a partial statement of the MTO recommendations without considering conditions stated for constrained urban areas. In addition, the TNS report failed to note that for urban freeways in areas where the 2 km minimum interchange spacing cannot be met, the MTO design guide states "[...] *it is necessary either to omit some of the interchanges in favour of grade separations or adopt some alternative means of combining interchanges to service closely located arterial roads.*" MTO recommendations for interchange spacings that are shorter for practical reasons and that considered different configurations including partial interchanges exist in the RHVP due to a frequent arterial road network, mature urban conditions, and other mitigation measures (such as weaving areas).
- The MTO design guide also stated that the interchange spacing is "*generally*" 2 to 3 km for urban areas and that interchanges are located at major arterials that may be less than 2 km apart when alternate means are used (such as interchange configurations, partial interchanges, or different types of connections to arterial roadways). One of the key objectives of the RHVP is to move traffic from one major arterial to another. Since Hamilton was planned and developed well before the construction of the RHVP, the spacing of these major arterials was not practically possible to alter to conform to the 2 to 3 km spacing outlined in the 1985 MTO design guide. In addition, eliminating RHVP access to major arterials to conform with interchange spacing recommended by the MTO may have resulted in more traffic congestion, which was a major reason for interchange spacing exceptions decided by the City during the initial planning stage.
- The TNS report did not consider an array of influencing factors (see Section 4.3.2) when its partial nominal safety conclusions were made.

4.4 Driver Expectations

Section 3.0 of the TNS report concluded that there were several "*potential expectancy violations within the RHVP design that may singularly or collectively challenge motorist expectation and proper decision-making*" and concluded on aspects of the RHVP (design speed, horizontal curve design, interchange spacing, and pavement friction). We will comment only on design speed and interchange spacing, as approved by the Commissioner. Any lack of commentary on absent issues does not imply our agreement.

4.4.1 Design Speed

TNS report concluded:

> *"Design Speed: Road users have priori* [sic] *expectations of acceptable operating speeds based on observations and experiences of driving on a range of freeways including 400-series highways that are generally designed to 20 km/h or more over the posted limit. Specific freeway elements that reflect a minimum design speed of 100 km/h on a controlled access freeway facility would be an expectancy violation to some road users, notwithstanding the 90 km/h posted speed.* [Section 3.0 of the TNS report]

[…] a design speed of 100km/h on a controlled access freeway facility would be an expectancy violation to some road users, notwithstanding the 90 km/h posted speed."
[Section 2.1 of TNS report]

We disagree with these statements.

- The RHVP is located in an urban area, which comes with a variety of constraints. Because of these constraints along with land-use compatibility, the initial planning and design documents of the RHVP (see Appendix C) decided to use a 100 km/h design speed for the geometric elements and construction of the RHVP. This decision was documented, and these documents follow the industry's general context-oriented design procedures and were approved by the Ministry of Environment and City Council. Since corresponding speed limits (i.e., 10 or 20 km/h lower than the design speed) for comparable urban conditions were communicated to highway users via speed limit and other warning signs, driver expectancy would be adjusted after exiting the provincial highway system.
- The RHVP has no mandate to provide the same level of service as 400-series highways because the RHVP is not part of the provincial highway network. Motorist expectations of different types of highway conditions are communicated via different types of signs and pavement markings regarding the prevailing posted speed limit. Therefore, different types of highways do not violate motorist expectancy as reduced speed and other local conditions were clearly communicated appropriately via signs and pavement markings by the City.
- Finally, the TNS report did not provide an analysis of design speed differences, nor did it perform any human factors analysis in support of the "*motorist expectancy violations.*" As indicated in our section on design speed (Section 4.2).

4.4.2 Interchange Spacing

The TNS report concluded:

> "*The majority of the interchanges on the RHVP were spaced less than specified in the 1985 MTO Design Guide, with the distance between the King Street and Queenston Road interchanges being the least and less than half the minimum value. This latter road section corresponded with a number of the lower design speed horizontal curves. Motorists may be ill-prepared to react to the conflicts, speed differentials and periodic congestion associated with closely spaced ramps.*"

We disagree with this statement that the RHVP design and planning process did not consider influencing factors and constraints while selecting interchange spacing.

- The TNS report predominantly refers to a nominal safety perspective, which could lead to completely different conclusions than when a substantive safety perspective is considered. The TNS report did not present any safety models to determine the relationship between the collision experiences and interchange spacing. As explained earlier, this relationship does not yet have supportable empirical evidence; hence, such direct conclusions as noted in the TNS report regarding the impact of interchange spacing cannot be made without appropriate analysis, such as a proper substantive safety review.

- The TNS report also did not consider other critical resources and local conditions for interchange spacing practices including conditions that prevent designers from achieving the MTO recommended interchange spacing.
- The TNS report also did not consider or specify critical safety elements such as weaving areas, which is the most important part of interchange spacing. As concluded earlier, weaving area distances on the RHVP generally satisfy MTO recommendations.
- As indicated earlier, the TNS report did not include the conditions noted by MTO for when recommended interchange spacing cannot be achieved because of environmental and other urban area constraints. Increasing interchange spacing can also increase traffic congestion as access would be limited to adjacent lands. Multiple factors (such as horizontal and vertical alignments of ramps and freeways within the spacing and at the approaches, ramp lengths, lighting, and similar factors) are linked to interchange spacing decisions and should be analyzed in conjunction with the interchange distance. None of these factors were noted or considered in the TNS report.
- The TNS report also did not provide a human factors analysis when it commented on driver behaviour such as the statement "*motorists may be ill-prepared*." Without a proper human factors analysis, these types of conclusions cannot be made in a deterministic manner, and it is not general practice among professionals to make such major conclusions without direct analytical evidence.

4.5 Contributory Factors

The TNS report stated the following regarding road surface friction in Section 5.0: "*It is my experience and opinion that reduced road surface friction would be the primary (i.e., highest ranking) contributory cause of an over-representation of wet road crashes.*"

Comments on a similar topic were provided in Section 3.0 of the TNS report.[49]

Road surface friction is out of the scope of this assignment. We have not performed specific analysis on matters pertaining to road surface friction. However, we noted the following:

- To determine whether pavement friction contributed to any collisions, typically collision reconstruction is performed for each incident using collision reports and the available information. This process considers skid resistance conditions and estimates the co-efficient of friction of the pavement surface during the collisions. Subsequently, the co-efficient of friction is compared to design assumptions stated in geometric design guidelines using design criteria. Without this rigorous safety assessment, a definitive conclusion, such as ranking surface friction (such as the network screening method in Section 4.2.1 of the HSM of possible crash contributing factors along a roadway segment for different collision types) as the primary cause of collisions, cannot be made in order to

[49] Section 3.0 stated "*It would be an expectancy violation for a motorist to experience lower traction abilities under routine dry and wet surface conditions encountered on a regular basis.*"

recommend safety countermeasures. The TNS report did not perform such an analysis or review relevant data of the RHVP in support of the above conclusions.

- Once a collision reconstruction is performed, a human factors analysis typically determines whether the noted pavement conditions (such as wet pavement or low pavement friction) would align with a driver's expectations of highway surface conditions and would be the cause of each individual collision. The TNS report did not perform a human factors analysis of a driver's expectancy violation as a result of specific surface conditions on the RHVP in support of the above conclusions. In addition, a collision reconstruction assessment needs to be performed to determine the exact cause of a collision during wet road conditions. TNS did not use any evidence based data to support their conclusion that reduced road surface friction is the primary contributory cause of an over-representation of wet road crashes. Ranking of causes of collisions without a detailed analysis, especially a collision reconstruction of collisions, is unreliable.
- Although it is believed that pavement friction affects the safety outcome, no definitive, specific threshold values have been established for pavement friction/texture to assure road safety.[50] Similarly, the HSM does not provide extensive models for different types of highways to estimate the measurable impact of pavement friction on collision rates. If statistical models are performed using local data, the difference in values between the suggested and actual pavement friction for all collisions has to be statistically significant to be able to make conclusions regarding the contribution of pavement friction on collisions. The model's results using different contributory factors can then be ranked accordingly. The TNS report did not perform any substantive safety assessment on the RHVP in support of the above conclusions.

4.6 Historic Collision Trends

We performed several selected collision trend analyses of major collision types to understand safety experiences on the RHVP as well as to respond to the TNS report. We also considered collision rates for the RHVP to replace weaker performance measures such as collision frequency. This section also summarizes the results and discusses appropriate procedures of analyzing before-and-after collision trends in a scientific manner, including industry recommended procedures.

4.6.1 Comments on Before-and-After Collision Analysis

The TNS report discussed collision experiences (particularly wet collision changes) before and after the 2019 road resurfacing and commented on the decrease in collisions in the 2017 to 2019 period and the 2020 to 2021 period.

The TNS report stated the following in Section 4.1:

[50] American Association of State Highway and Transportation Officials (AASHTO). (2009). *Guide for Pavement Friction.* AASHTO. Washington, D.C.

"*Figure 17* [reproduced below as Figure 2] *shows that the proportion of RHVP collisions with wet road surface conditions slightly decreased between 2017 to 2019, and experienced larger decreases in 2020 and 2021.*

It was noted that the RHVP was resurfaced in the Summer of 2019, and subsequent testing in September 2019 found that the friction values were higher compared to friction values collected in 2014. While wet road surface collisions can be impacted by other external factors (i.e., active weather conditions and operating speeds), the proportion of collisions during wet road surface conditions appears to be significantly lower in Q4 of 2019 compared to previous years. This trend generally aligns with the findings shown Figure 17" (reproduced below).

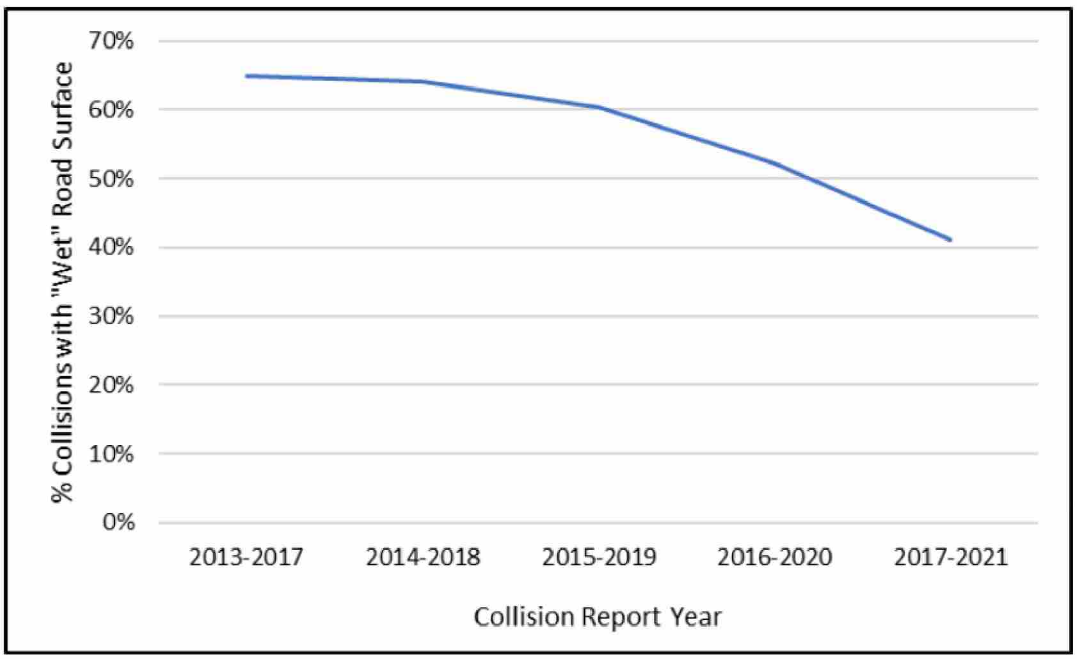

Figure 17: Proportion of Collisions with Wet Road Surface Condition[49].

Figure 2: Collision trend for wet surface collisions (Reproduced from the TNS report).

As detailed below (see the following for detail), we do not agree with the TNS report's conclusions for two reasons:

1) Although the TNS report acknowledges that collisions are random occurrences and "*definitive conclusions cannot be drawn based on four months of collision data*," the report contradicts this statement and concludes the "*proportion of collisions during wet road surface conditions appears to be significantly lower in Q4 of 2019 compared to previous years*." The TNS report used an insufficient data set in completing its analysis. As such, the conclusions it drew are not reliable.

2) The proportion of wet condition related collisions was already declining between the 2014-2018 and 2015-2019 periods as per the TNS report's Figure 17 (Figure 2).

4.6.2 Proper Method of Before/After Analysis

Comparing before and after collisions for certain collision mitigation measures is known as the "*observations method of before-and-after collision analysis*," which was developed by prominent Canadian safety expert Dr. Ezra Hauer. Later, his approach, including other scientific contributions on this subject, was summarized and used to develop the recommended procedures in the HSM document. The HSM details two types of before-and-after collision analysis, described below.

Type One: Implementing the Before/After Comparison-group Safety Evaluation Method (HSM Section 9.4.2)

The first method is referred to as the "*Before/After Comparison group*" and involves comparing the subject roadway which implemented safety mitigation measures to other roadways that did not implement any specific safety treatment.

The before/after comparison-group safety evaluation method is similar to the Empirical Bayes before/after method except that a comparison group is used, rather than a Safety Performance Function (SPF), to estimate how safety would have changed at the treatment sites had no treatment been implemented. The following provides a step-by-step overview of data needs and inputs of the before/after comparison-group safety effectiveness evaluation method.

"*The data needed as input to a before/after comparison-group evaluation include:*

- *At least 10 to 20 sites at which the treatment of interest has been implemented*
- *At least 10 to 20 comparable sites at which the treatment has not been implemented and that have not had other major changes during the evaluation study period*
- *A minimum of 650 aggregate crashes at the comparable sites at which the treatment has not been implemented*
- *3 to 5 years of before crash data is recommended for both treatment and nontreatment sites*
- *3 to 5 years of after crash data is recommended for both treatment and nontreatment sites*
- *SPFs for treatment and nontreatment sites*

An evaluation study can be performed with fewer sites and/or shorter time periods, but statistically significant results are less likely."

Type Two: Implementing the Safety Evaluation Method for Before/After Shifts in Proportions of Target Collision Types- (HSM Section 9.4.3)

The second type of analysis, referred to as the "*before/after shifts in proportions of target collision types*," involves evaluating the proportion of specific collision types without comparing to other similar roadways. The HSM describes the methodology, data needs, and analysis inputs as follows:

"The safety evaluation method for before/after shifts in proportions is used to quantify and assess the statistical significance of a change in the frequency of a specific target collision type expressed as a proportion of total crashes from before to after implementation of a specific countermeasure or treatment. This method uses data only for treatment sites and does not require data for nontreatment or comparison sites. Target collision types (e.g., run-off road, head-on, rear end) addressed by the method may include all crash severity levels or only specific crash severity levels (fatal-and-serious-injury crashes, fatal-and-injury-crashes, or property damage-only crashes)."

The following provides a step-by-step overview of the method, data needs, and analysis inputs for conducting a before/after safety effectiveness evaluation for shifts in proportions of target collision types.

"The data needed as input to a before/after evaluation for shifts in proportions of target collision types include:

- *At least 10 to 20 sites at which the treatment of interest has been implemented*
- *3 to 5 years of before-period crash data is recommended for the treatment sites*
- *3 to 5 years of after-period crash data is recommended for the treatment sites*

An evaluation study can be performed with fewer sites and/or shorter time periods, but statistically significant results are less likely."

To fully understand the importance of having a sufficient data set for before/after collision analysis, we have provided an analysis of the RHVP collision rate, below.

Assessment of Collision Rates on the RHVP Before 2019

Analyzing collision frequency is the simplest form of collision analysis. It is the method of determining the number of collisions at a specific roadway segment. However, analyzing collision frequencies can be limiting and does not provide a fulsome depiction of what may be occurring on the roadway in terms of collision history and roadway safety.

In contrast, calculating collision rates is a more accurate method of determining the safety of a roadway segment because it incorporates the length of the segment and the traffic volume into the calculation (i.e., exposure data). This method is typically used to determine relative safety compared to other similar roadways, segments, or intersections. More advanced methods of determining the safety of a roadway or highway are available (such as using safety performance functions and the Empirical Bayes method); however, for our purposes, collision rates were sufficient.

In preparing our analysis, we used collision data for the years 2014 to 2018.[51] Industry best practice recommends using 3 to 5 years worth of safety data.[52] In addition, our analysis was limited to the available years of volume data that was provided to us to calculate crash rates.

[51] The collision data was filtered to ensure the data was as accurate as possible. The following filters were applied: RHVP northbound and southbound collisions, excluded non-reportable collisions, excluded intersection collisions, excluded collisions with traffic signal or stop sign traffic control, excluded ramp collisions.
[52] Highway Safety Manual – Part B, Chapter 5 – Diagnosis. (2009). Federal Highway Administration.

To determine the collision rates for the RHVP, we were also provided with average annual daily traffic (AADT) for the years 2014 to 2018 for segments of the RHVP. The provided AADT had some missing segments along the RHVP; however, a volume-balancing method[53] was used to ensure that there were volumes for the entire length of the RHVP, especially in between ramps, to calculate rates for the entire roadway.

To calculate the collision rate for each segment, the following formula was used for each segment:

$$Collision\ Rate = \frac{A * 1{,}000{,}000}{365 * L * AADT}$$

Where:

Collision rate = collisions per million vehicle kilometres travelled

A = total collisions for 5-year period

L = length of segment in kilometres

AADT = total AADT for 5-year period (used separately for each RHVP section to estimate collision rate)

The total average collision rate that we calculated for the RHVP for the years of 2014 to 2018 was 0.69 for northbound traffic and 0.43 for southbound traffic. Table 3 illustrates the collision rates for each segment of the RHVP for each direction.

After reviewing the collision rates, we found the RHVP achieved the safety rate as per its initial planning collision rate (1.0 collision per million vehicle kilometres travelled for provincial freeways) noted in the 1982 EA report.[54] Note that the CIMA report on comparable highways collision rates in Ontario[55] estimated that the overall weighted average collision rates for Highway 403 was 0.81, Highway 406 was 0.78, Highway 7/8 was 0.66, and Highway 8 was 0.70. When compared with the RHVP overall collision rate, we conclude that RHVP safety performance was similar or in some cases better than other provincial highways.

Table 3: RHVP collision rate per segment.

From	To	Northbound	Southbound
Dartnall On Ramp	To Mud Off Ramp	0.14	0.33
Mud Off Ramp	Highway Bridge	0.71	0.44
Highway Bridge	Green Hill Off Ramp	0.28	0.09

[53] Volume balancing is a method of equating volumes on either side of an intersection (or on- and off-ramp) to ensure that entering and exiting vehicles match. For example, for a roadway like the RHVP with on and off ramps, it considers the number of vehicles in one direction and adds the number of vehicles entering the roadway from the on-ramp and subtracts the number of vehicles exiting on the off-ramps.
[54] Environmental Assessment Submission. (1982). Section 5.4.2, Page 5-42.
[55] Malone, B. *Lincoln Alexander Parkway / Red Hill Valley Parkway Collision Rates*. (January 18, 2019). CIMA.

From	To	Northbound	Southbound
Green Hill Off Ramp	Green Hill On Ramp	0.93	0.20
Green Hill On Ramp	King Off Ramp	0.91	0.45
King Off Ramp	Queenston Off Ramp	1.30	0.88
Queenston Off Ramp	Queenston On Ramp	0.59	0.91
Queenston On Ramp	Barton Off Ramp	0.30	0.36
Average Weighted		0.69	0.43

Collision Rates After 2019

Due to the limited collision data available after 2019, we were unable to calculate the collision rate to provide a definitive conclusion on the change in collision rates after the resurfacing of the RHVP.

4.6.3 Limitations of the TNS analysis

The TNS report based its analysis on an insufficient data set. The HMS is clear that equal amounts of data (3 to 5 years of data) are needed to perform this type of collision analysis to have statistically significant results. In addition, large datasets (10 to 20 sites) are required. TNS used less than a year's worth of data, contrary to the prescribed approach in the HMS.

After the resurfacing of the RHVP in the summer of 2019, there was only about six months of data available before the first lockdown of the Covid-19 pandemic began in March-April 2020. During the Covid-19 pandemic, traffic volumes were dramatical reduced and travel speed was increased.[56] After March 2020, the traffic volumes, speed, and collision data changed drastically due to lockdown-impacted measures including work from home.

The effects that the Covid-19 pandemic had on collision trends are currently being evaluated and, as such, pandemic data from 2020 to 2022 cannot be used for before/after collision analysis. Given that only six months of comparable data was available after the RHVP resurfacing and given that the HSM mandates an equal number of years as a mandatory precondition for before-and-after collision analysis, the TNS report comparison and its conclusions regarding the impact of the RHVP resurfacing are inappropriate, unscientific, and unreliable as per industry standards and processes described by the HSM document. The TNS report and its conclusions do not follow either of the before-and-after methods in its brief collision analysis section.

The proportion of wet road condition related collisions were already declining between the 2014-2018 and 2015-2019 periods as illustrated in the TNS report figure reproduced above (Figure 2). Therefore, the conclusions that the 2019 RHVP resurfacing had significantly altered the proportion of wet road related collisions are not supportable, particularly without a proper substantive safety assessment per the prescribed procedure in the HSM, discussed above.

[56] Kouchakzadeh, M., Bayanouni, H., & Roorda, M.J. (2021). Analyzing Impact of the COVID-19 Pandemic on GTHA Traffic Congestion Using Travel Speed Data. Executive Summary, August 25, 2021, University of Toronto.

4.6.4 Assessment of Collision Types

The TNS report concluded the following regarding the type of collisions on RHVP (Section 4.2):

> "*The historic proportion of SMV collisions was higher compared to provincial and City averages and resulted in SMV collisions being the most prominent impact type on RHVP, which is usually not typical for a freeway facility. Generally, rear-end collisions are the most prominent impact type on freeway facilities since they are associated with congestion and start-stop behavior.*"
>
> "*Poor road surface conditions, including lower pavement friction, is one of the primary contributory factors to an over-representation of SMV collisions on urban freeways.*"

We generally disagree with these conclusions for three reasons:

1) TNS did not use comparable collision type data for freeways. Specifically, the TNS report did not provide SMV collision rates for freeways from provincial or city-level collision experiences but regardless concluded that the RHVP had a higher proportion of collisions.
2) There is no reference or support for the conclusion that rear-end collisions are the most dominant impact type in freeway facilities. In fact, due to the absence of traffic control devices or the lack of intersections, SMV or rear-end collisions are typically common types of collisions on freeways.
3) As indicated in our analysis below, our analysis shows that, contrary to the findings in the TNS report, there were no noticeable changes in the rate of SMV collisions when SMV collisions were properly plotted (Figure 3).

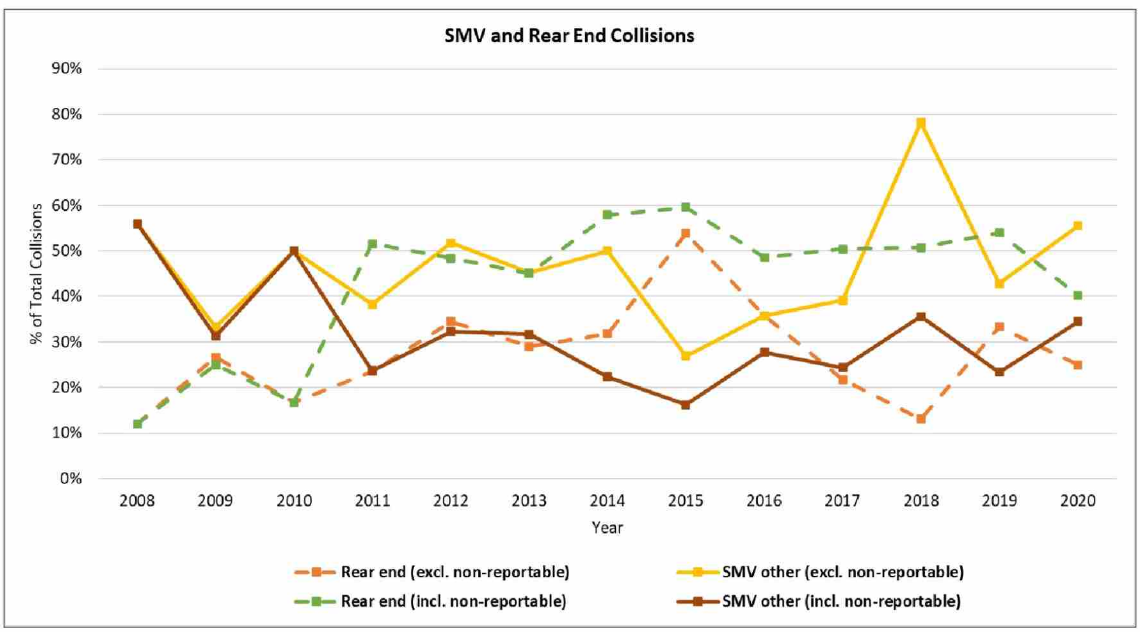

Figure 3: Collision trends for SMV and rear-end collisions on the RHVP (Data Source: City of Hamilton).

To verify actual collision trends on the RHVP, we reviewed and estimated the percentage breakdown of collisions based on the initial impact type on the RHVP for each year, focusing specifically on rear-end and single motor vehicle (SMV) collisions. SMV collisions may include run-off-road or roll-over collisions, hitting debris on the roadway, or hitting a roadside object. Typically, SMV collisions also include hitting a pedestrian or cyclist, but this is unlikely to occur on a freeway such as the RHVP.

The collision trends for these types of collisions are summarized in Figure 3 for all collisions, both excluding and including non-reportable collisions.[57] Using the total number of collisions that identified an impact type for any specific year, the percentage of rear-end and SMV collisions was estimated for each year from 2008 to 2020 for the RHVP.

When non-reportable collisions are excluded, the average percentage of rear-end and SMV collisions are 27% and 46%, respectively. When non-reportable collisions are included, the average for rear-end and SMV collisions are 43% and 31%, respectively.

This higher proportion of rear-end collisions compared to SMV collisions when non-reportable collisions are included is likely due to the fact that rear-end collisions are typically low cost to repair, which would classify them as non-reportable at the time of collision.

There is no significant change in SMV or rear-end collision trends when all collisions are considered. Collisions are random events, so when we look at the standard deviation (the variation from the average value) for single motor vehicle collision sets of data in Figure 4, for instance, the standard deviations vary from 0.11 to 0.15, which means there is small variability of the dataset from the mean. The vertical bars show the standard deviation, and the horizontal line is the average of the data set. The standard deviation shows the variance from the average value. Based on this analysis, we conclude that there was no significant change in major collision types on the RHVP over the past 12 years of operation.

[57] 'Non-reportable collisions' refer to collisions that did not meet the threshold of mandatory police reporting. Note that non-reportable collisions started to appear in 2011.

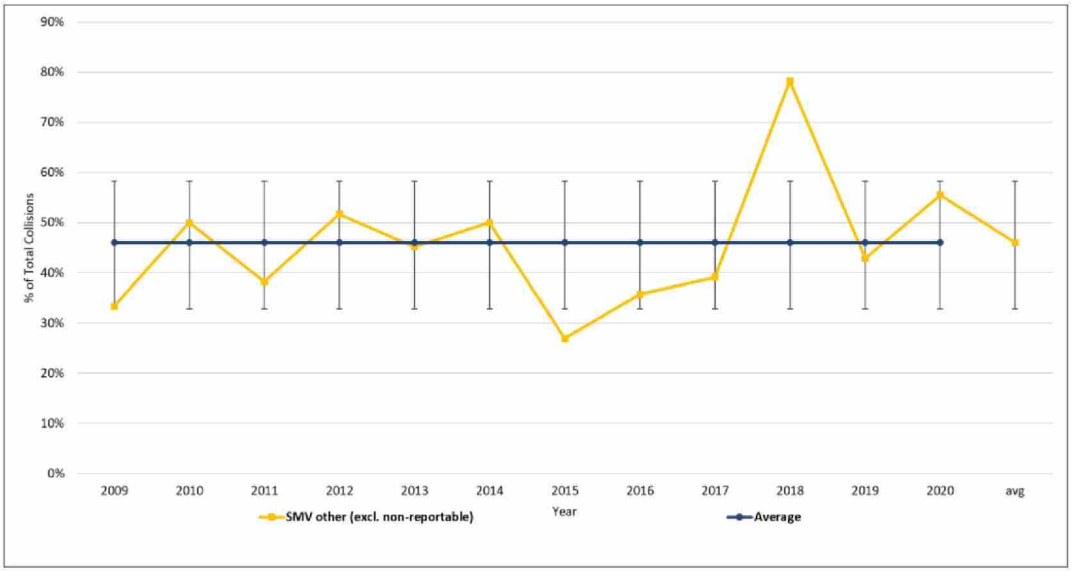

Figure 4: Example data set with standard deviation and average.

Note that the City's annual collision data reported 30.1% SMV collisions and 48.3% rear-end collisions in 2019. 30FE estimated that the average for SMV and rear-end collisions roughly matches with the data in the City's collision reports.

In conclusion, the TNS report did not present an analysis using statistical models, nor did it perform a collision analysis to understand the causes of the SMV collisions. Reference to pavement friction or poor surface conditions is arbitrary without any supportive collision analysis. Concluding that surface conditions were the cause of these collision without an appropriate before-and-after analysis method (Section 4.6.1) a change was made to the surface is unreliable and it is not industry practice to make such a major conclusion without proper statistical analysis, particularly substantive safety considerations.

5.0 CONCLUSIONS

Our review and analysis of this incident indicates that:

- Based on our review of the initial planning and design documents of the Red Hill Valley Parkway ('RHVP') from 1982 until 2006, we conclude that these documents clearly stated their geometric design assumptions and other design decisions per general professional practices and procedures for planning and designing new urban highway. These documents were later approved by provincial and local decision-making authorities.
- Major planning and design decisions were selected or modified (such as the design speed of 100 km/h, interchange spacing, and highway alignment) in the RHVP planning and design documents to reflect the environmental constraints, land-use, and local urban contexts. These decisions followed the industry process of context-oriented use of geometric design guidelines and associated design variations to reduce the impact of a new highway on the environment and surrounding living areas.
- The initial design speed of 100 km/h met the recommendations in the MTO design guide and TAC guideline when the RHVP design documents were produced. Per the MTO, a change in design speed does not significantly alter common geometric features, and other directly impacted features could change depending on the scale of design of speed changes. The TNS report did not provide any analytical evidence, substantive safety analysis, or human factors assessment in support of its conclusion that there were "*significant disparities*" in CIMA making recommendations using a different design speed (the 110 km/h design speed used on provincial highways) than the selected RHVP design speed of 100 km/h.
- Interchange spacing shorter than what the MTO design guide recommended was decided at a few locations due to the existing road network, adjacent land-use, and other natural or built environment constraints. Flexibility regarding this design decision was allowed in the MTO design guide. This is not unique to the RHVP. Based on the interchange spacings of other comparable highways in Ontario, we conclude that other comparable urban highways also had interchange spacings shorter than what was recommended by the MTO. An accurate quantification of the safety impact of different interchange spacing decisions was not available per the safety manual except at weaving areas, and the design of this area on the RHVP roughly aligned with the MTO design guide. The TNS report did not provide any analysis or statistical models or human factors assessments in support of its conclusions that shorter interchange spacing would lead to violations of motorist expectations.

- We disagree with the TNS report's conclusions regarding expectancy violations from a design speed and interchange spacing perspective as the report relied only on a partial statement of MTO recommendations without considering local constraints. The TNS report did not refer to MTO guidance for constrained urban areas, contained no discussions of the consequences of a longer interchange distance or the impracticality of altering local road networks, and only considered a nominal safety perspective, which is not always correct regarding the safety outcome of selecting certain geometric features. Similarly, the TNS report did not refer to local constraints for selecting a design speed and the necessity of CIMA using a design speed for its speed analysis to make recommendations. The TNS report did not analyze weaving sections, did not provide a safety performance analysis for different design speeds, and did not present the required human factors assessment or substantive safety modelling to make major conclusions regarding driver expectancy violations.
- We disagree with the TNS report's conclusions that the proportion of major collision types were significantly changed over a 12 year period or before and after any specific year. Our historical trend analysis indicated no major anomaly or decrement in two major collision types over a 12 year period.
- We disagree with the TNS report's conclusions that wet road surface related collisions were significantly lower after the 2019 resurfacing. There was insufficient collision data in the TNS report's high-level analysis (only six months before the Covid-19 pandemic and unreliable data during the pandemic) considered after resurfacing. In addition, the TNS report did not perform the recommended process of before-and-after safety assessment as per the Highway Safety Manual.
- Based on collision rate comparisons provided to 30FE, the RHVP does not appear to perform significantly differently when compared to other highways or expressways in urban areas in Ontario with respect to safety performance, and it roughly aligns with the City's initial collision rate target for uninterrupted urban highways.

APPENDIX A: CURRICULUM VITAE

CURRICULUM VITAE

Dewan Masud Karim, M.A.Sc., MITE, P.Eng., PTOE

(416) 368-1700 | dkarim@30fe.com

902 – 40 University Ave., Toronto ON M5J 1T1

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EXPERT SUMMARY

Mr. Dewan Karim is Practice Lead of the Transportation Engineering and Safety Group at 30 Forensic Engineering. He graduated from the University of Tokyo with a Master of Engineering in Infrastructure Planning and a Master of Applied Science in Transportation Safety from Ryerson University. Dewan has focused on transportation engineering, planning, and traffic safety issues since 2000 and received his Professional Engineer designation in 2008 (Ontario) and 2021 (British Columbia and Nova Scotia). He has been a Forensic Engineer in the Collision Reconstruction Group at 30 Forensic Engineering since September 2018. Dewan has worked in public and private sectors in both Japan and Canada for 22+ years of his career in pioneering creative ideas in transportation engineering and planning. Dewan has investigated strategic safety and location-specific collisions from traffic engineering and safety regulations for all street users including motor vehicles, cyclists, pedestrians, off-road and commercial vehicles, trucks, and motorcycles. He has also researched safety aspects of transportation planning and street design issues including Vision Zero plans for several municipalities in Canada. He has been invited as a keynote speaker for local and international conferences and regularly provides courses on safety and transportation planning issues at conferences, webinars and workshops. His creative ideas have won several awards, including “Best Planning System”, Disrupting Mobility Summit by MIT Media Lab, Project of Year by ITE in 2015, and has authored a chapter in the Disrupting Mobility book. Recently, he signed a sole publication book contract (Titled – Our Mobility DNA) with Taylor and Francis which is expected to be published in early 2022.

SPECIALIZED PROFESSIONAL COMPETENCIES

Transportation Engineering, Operations and Safety:

- Passenger and commercial vehicles, motorcycles and recreational vehicles, cyclists, and pedestrians
- Specialized in traffic engineering and safety regulations in Ontario
- Assessment of traffic safety using local standards, manual and guidelines
- Area safety studies for intersections, street segments and other roadway locations
- Strategic safety and planning policies that influence overall traffic safety outcome
- Safety assessment of new transportation modes such as carshare, rideshare, bikeshare, scooters
- Stop signs, speed limit, and warning signs assessment for roadways and highways

- Intersection collision including turning movement, traffic signal, pavement marking assessment
- Visibility and safety assessment for road curvature, vertical crest on roads and highways
- Motorcycle safety assessment for road surface defects and road geometry assessment
- Streetcar and bus loading and unloading safety and operational assessment
- Turning lane configuration, right-turn safety assessment
- Smart data to identify safety trends prior to actual incidents
- Transit user safety and rail infrastructure assessment to improve user or operational safety
- Roadside safety for rural and urban highways and roadways
- Midblock and intersection street illumination and visibility assessments
- Midblock pedestrian and cyclists safety and crossing assessment
- Route engineering assessment and permit approval for long-combination vehicles (LCVs)
- Rail proximity derailment protection and safety plans for land-use policies for rails agencies
- Rail proximity derailment protection design and safety plans for private land-use developments
- Property access and driveways safety and operations reviews
- Safety perspective for senior citizens, children, school travel and disable persons
- Winter maintenance for private and public roadways, parking lots, plazas, shopping malls, business parks, apartment complexes, condominium access roads and private walkways
- Slip and fall safety assessment in winter on roads, parking lots, sidewalks, and trails
- Comparing minimum maintenance standards, highway traffic act, OTM manuals, master plans for winter maintenance incidents and collisions
- Investigations for collisions on ice roads and winter tracks
- Parking design, planning, configurations, access, and safety performance
- Temporary work conditions safety assessments for vehicles, trucks, pedestrians, and cyclists
- Road geometry and safety assessment for private roads and access driveways
- Roundabout safety and traffic calming measures and safety assessments
- Standard of care of design construction related safety assessment
- Collision investigations on bridge, geometric design, safety review

ACADEMIC BACKGROUND

Master of Applied Science (Civil Engineering), Ryerson University, Toronto, Ontario, 2006

Master of Engineering (Infrastructure Planning), University of Tokyo, Japan, 2000

Bachelor of Applied Science (Civil Engineering), Bangladesh University of Engineering and Technology, Dhaka, Bangladesh, 1998

Dewan Masud Karim, M.A.Sc., MITE, P.Eng., PTOE

PROFESSIONAL EXPERIENCE

30 Forensic Engineering

Practice Lead — Transportation Safety
March 2022 — Present, Toronto, ON

- Lead investigator for transportation facility design, operations, and maintenance files for public, legal and insurance sector clients.
- Prepared report and performed analysis for collision at traffic signal intersections.
- Prepared report and performed street illumination and visibility of intersection geometry.
- Prepared report and performed analysis for intersection safety in rural and urban areas.
- Prepared report and performed analysis for winter maintenance of public roadways, highways, parking lots and plazas.
- Prepared report and performed analysis for ice roads collision investigation in Simcoe County.
- Prepared report and performed analysis for route permit and engineering assessment of safety and operations of Long-combination vehicles.
- Prepared report and performed analysis for pedestrian and cycling collision on sidewalks, trails, crossing in midblock and intersection locations in Ontario and British Columbia.
- Prepared report and performed analysis for rail crossing collisions and safety performance of crossing devices.
- Prepared report and performed analysis for collision during temporary work conditions on highways, roads, sidewalk, utility projects in Ontario and Nova Scotia.
- Prepared report and performed analysis for rail derailment protection plan for secondary plan and private developments.
- Lead transportation safety training.
- Transportation safety and traffic engineering peer review services.

Senior Associate — Transportation Safety
September 2018 — March 2022

City of Toronto, Transportation Planning

Senior Transportation Planner and Acting Manager
2013 – 2018, Toronto, ON

- Developed evidence-based safety Vision Zero approach for community planning.
- Led several active transportation guideline projects to improve walking and cycling in suburban environments.
- Managed a team including two student interns, completed two master planning area transportation plan reports, introduced smart data and created several state-of-the-art technologies that reveal the true nature of transportation behaviour, and develop innovative countermeasures without expensive infrastructures.

- Contributed to senior staff team, reviewing council reports and resolved critical mobility issues.
- Led a successful effort to introduce North America's first mandatory, innovative, shared and on-demand mobility infrastructures and facilities as part of the new development process to update Toronto Green Standards.
- Developed North America's first innovative mobility master plan, Consumers Next, using quantitative multimodal travel demand model, smart and shared mobility infrastructure assessment, creative implementation strategies, innovative resource and collaboration and new technological applications.
- Introduced "Mobility Placemaking", a new form of public space from unused vehicle space and inclusion of new mobility modes through collaborative approach with urban design, planners, and university researchers.
- Successfully negotiated with MTO for safer walking/cycling facilities and introducing innovative custom projects with Metrolinx to introduce Toronto's first shared-transit concept, comprehensive vehicle-bicycle sharing scheme, smart mobility information system to improve transit access and shorter trips.
- Implemented new "EcoMobility", one-stop multimodal service points and Toronto's first planned shared mobility neighbourhood with cross-functional team and area developers at Tippet-Wilson Regeneration area.
- Successfully negotiated with developers and agencies to install realtime digital technologies, on-demand trip and parking technologies, redesign building frontage for shared and autonomous vehicles.
- Introduced quantitative multimodal transport assessment for all development projects including comprehensive application of travel demand measures, and smart parking management strategies.
- Managed and coordinated several area master plans and environmental assessment projects, resolved critical difference between the stakeholders and completed or reviewed finals reports, presented to council members.
- Develop several area plan policies by introducing "detail policy" techniques that resolved practical challenges while introducing new mobility infrastructures and create new public space along transit corridors.
- Utilizing traditional traffic engineering approach and standards, identify unused/underutilized vehicle spaces and redistribute the space to sustainable mode users.
- Developed evidence-based safety Vision Zero approach for community planning through downsizing and microscaling infrastructures to avoid oversized streets and compact intersection intersections that minimizes negative impacts on human, local community, and environment.
- Implemented creative land-use and transportation policies through mobility and parking incentives for mixing of uses that maximize shorter trips and minimize the needs for long-distance trips Innovative.
- Led several active transportation guideline projects to improve walking and cycling in suburban environment, Complete Interchanges, School Travel Planning, School Area and Site Design to name a few.
- Coordinated several transit projects for review and feedback e.g. Finch, Sheppard and Eglinton LRT stations.
- Collaborated with cross-border municipalities for policy and transit or infrastructure project coordination including Yonge-Steeles Mobility Hub, Markham and Steeles area plans.

- Introduced smart transport information, bicycle and pedestrian amenities requirements through development projects, university and college parking and multimodal policies, and collaboration with consulting industry.
- Collaborated with University of Toronto and Ryerson university research groups, and startup companies to test pilot projects through several research and development projects.

WSP (Genivar Canada)

Project Manager and Transportation Planning Engineer
2012 – 2013, Markham, ON

- Prepared technical reports for corridor and intersection projects.
- Investigated safety aspects of residential and commercial site developments.
- Prepared technical proposal for competitive bidding, helped to win two master plans and an EA project, managed transportation team to conduct transportation master plans, secondary studies, performed project management and coordination with project stakeholders, submitted final reports and presented the study findings to clients.
- As a deputy project manager, created a unique concept of quantitative multimodal planning method for Markham Centre area study using "person" capacity, MMLOS concept, and 4-step multimodal transportation modeling process and accommodate future demand through sustainable transportations and TDM options and achieve the target modal split without degrading quality of life of the existing community.
- As a deputy project lead for King Township Transportation Master Plan, managed planning team to develop rural multimodal framework, assessment of existing infrastructure needs, identified gaps and opportunities.
- Developed evidenced based and quantitative model for TDM master plan for Markham Centre including car-share, bike-share, carpool, shared parking, bicycle parking rate, and created policies to implement the TDM program and services.

City of Oshawa

Senior Transportation Planning Engineer
2009 – 2012, Oshawa, ON

- Completed long-term draft "Active Transportation Master Plan", comprehensive network screening for collision assessments and safety performance assessment for all major streets.
- Managed a comprehensive transportation infrastructure review for mast planned areas. Liaised developers/external agencies to achieve safety policies including cycling network, pedestrian promenade, transit facilities, community traffic safety plan and area-wide traffic roundabout safety.
- Played a key role in planning and design of City's first complete street and bike lane, first human-scale mini-roundabout planning/design, first developer paid dedicated pedestrian and cycling pathway and developed concept of City's first dedicated cycling infrastructures on major arterial corridors.
- Managed "Smart Commute Oshawa" project, prepared TDM plan and implementation strategy, developed and promoted Carpool programs and brochures, initiated and executed cycling tourism programs, organized events such as Bike-to-Work Week and Walkable Oshawa projects, resulting in the "Bicycle Friendly Communities Award".

- Managed and chaired the successful implementation of the first bike summit in Durham Region, organized Walkable Oshawa workshop that led City council's recognition of International Pedestrian Charter.
- Managed reviewing process of Highway 407 expansion, active transportation, Transitway facilities, coordinated departmental comments for planning and design modifications, updated City Council about progress.
- Reviewed several transportation and transit EA projects including Long Term Transit Strategy, Highway 2 BRT, Conlin Road, Ritson and Columbus, Gibb-Olive Extension, Harmony Road, GO Transit maintenance and eastern track expansion to Bowmanville, provided planning and design recommendations to agencies and City Council.
- Developed planning and design concept of a dedicated bus loop at South Oshawa Community Centre.
- Represented City's planning branch at Development Committee and City Council, and prepared report.

IBI Group

Transportation Planning Engineer
2006-2009, Toronto, ON

- Researched on safety and network performance of Fused-Grid street network.
- Planned and designed several roundabouts in Waterloo and Barrie.
- Action transportation planning and safety for Hamilton Pedestrian Plaza, one-way to two-way street conversion, review of five-year transportation master plan.
- Conducted traffic impact study for GTA region projects: evaluated corridor traffic operations, performed future demand and infrastructure needs, presented findings and prepared reports for client.
- Performed an innovative mixed-use transportation planning and operational strategies for Langstaff Gateway & Markham Centre Master Plan, prepared supporting documents for OMB, conducted future Langstaff/Unionville GO station parking strategies and station access plan for future subway and Richmond Hill Centre station.
- Developed station planning and conceptual design plans, traffic operational strategies for MTO's 407 Transitway stations in York/Toronto area, recommended infrastructure requirements for transit operations.
- Developed a multimodal station planning and conceptual design for Oakville GO Station area; managed Whitby, Pickering, Burlington GO Transit station's area, parking, local transit, demand management and active transportation network; recommended and presented findings to the City, MTO, and GO Transit.
- Conducted multimodal transportation assessment studies for Riverbend and Andover Trails planning for City of London; recommended alternative road improvements, presented results and prepared reports to City staff.
- Conducted sustainable transportation planning strategies, area-wide traffic management using strategic roundabout and long-term infrastructures evaluation for the City of Waterloo's Transportation Master Plan.

University of Tokyo, Japan Pavement Corporation and Ryerson University

Research Assistant and Transportation Engineer
1998-2006, Tokyo, Japan and Toronto, ON

- Conducted and organized in-depth study on holistic view of human interaction with roadway planning and design elements to improve collision safety countermeasures at urban intersections.
- Implemented ITS driver safety supporting system that assists drivers dealing with dangerous situations.
- Developed new intersection safety function model and countermeasures assessment for 6000 intersections in Tokyo and 400 intersections in Toronto.
- Confirmed underlying cause of intersection collisions: a lack of interaction between the road participants through four-legged intersection safety research.

PROFESSIONAL LICENSES AND CERTIFICATIONS

- Professional Engineers of Ontario (PEO), Member, 2008
- Association of Professional Engineers and Geoscientists of Alberta (APEGA), Member
- Professional Engineers and Geoscientists of the British Columbia, Member, January 2021
- Association of Professional Engineers of Nova Scotia, Member, February 2021
- Professional Traffic Operation Engineer (PTOE), Certified by ITE and TPCB, 2008

PROFESSIONAL SOCIETIES AND ASSOCIATIONS

- Professional Engineers of Ontario (PEO), Member
- Professional Engineers and Geoscientists of the British Columbia, Member
- Association of Professional Engineers of Nova Scotia, Member
- Institute of Transportation Engineers, ITE, Member
- Canadian Transport Research Forum, CTRF, Member
- International Municipal Signal Association, IMSA, Member
- Canadian Society of Civil Engineers, CSCE, Member
- American Society of Civil Engineering, ASCE, Member

AWARDS AND ACHIEVEMENTS

- ITE Project of The Year 2015: Innovative Mobility Master Plan for Toronto's Planning Areas, Toronto, 2015.
- Best Planning and Policy: "Innovative Mobility Master Plan: Connecting Multimodal Systems with Smart Technologies", Disrupting Mobility Summit, MIT Media Lab, Cambridge, November, 2015.
- Initiated and lead Walkable Oshawa & official recognition of "International Charter for Walking", 2012.
- Played an instrumental role to win "Bicycle Friendly Communities Award" for City of Oshawa, 2011.
- Special recognition by PEO West Toronto Chapter for leading "Clean Train Policy" research study, 2010.
- TAC & OGS Scholarship, 2006, Ryerson Graduate Scholarship, 2004-06, AUTO21 research grant, 2006.

- Monboshu Scholarship, Ministry of Education, Japan; Research Travel Grant, University of Tokyo, 1998.

SPEAKING ENGAGEMENTS

- "Sustainable Safety Principles, and Design Strategies in an Era of Innovative Mobility Planning", Webinar, 30 Forensic Engineering, 2021.
- "Integrating Smart Urban Mobility and City Planning for Livable", Keynote Speaker, Frankfurt, 2019.
- "Integrating Active Transportation Demand and Supply Assessment with Sustainable and Shared Mobility Modes", Annual CITE Conference, Ottawa, 2019.
- "Realising seamless integrated urban mobility", Panelist, Smart Cities Global Summit, Algiers, 2018.
- "The Future Multimodal Mobility for a Liveable City", Keynote Speaker, Smart City Expo, May 8, 2018.
- "Rethinking Mobility Planning and Redesigning Cities for Innovative Mobility System", Keynote Speaker, 1st International Urban Mobility Dialouge, Berlin, November 1-4, 2017.
- "Multimodal Planning Beyond Toronto's Urban Core", Webinar with CEO, StreetLight, Nov 2017.
- "Redesigning Cities & Public Space for Innovative Mobility System", World Design Summit, Oct 18, 2017.
- "Creating Innovative Mobility Ecosystem for Urban Planning Areas", AV Workshop, USA, April 2017.
- "Innovative Mobility Master Plan: Connecting Multimodal Systems with Smart Technologies, Disrupting Mobility Summit", MIT Media Lab, Cambridge, MA, November, 2015.
- "Promoting Active Transport Through Land-Use Planning", Urban Trans. Summit, Toronto, ON, March, 2012.
- "Streets for People: An Evidence-Based Bicycle Planning", Complete Street Forum, Toronto, ON, April 2011.

BOOKS

- "Our Mobility DNA" – signed full book contract with Taylor and Francis, expected to publish in 2021.
- Chapter author "Creating an Innovative Mobility Ecosystem for Urban Planning Areas", Springer, 2017.

ACADEMIC PUBLICATIONS

Journal Publications

- Karim D.M. and Shallwani,T., Toward a clean train policy: diesel versus electric , the Ontario Centre for Engineering and Public Policy (OCEPP), Vol.2, No.3, pp. 18-22, 2010.
- Karim D.M., Ieda H., Risk Evaluation Model for Traffic Accident at four-legged Signalized Intersections, Journal of the Eastern Asia Society for Transportation Studies, EASTS, Vol.4, No.5, pp.343-358, 2001. (Conference presentation on 24-26 October, Hanoi, Vietnam, 2001).
- Alam, M.J.B., Karim, D.M. and Hoque, A.M.(2001), Macroscopic Model for Planning and Management of Domestic Air Transportation in Bangladesh, Journal of Civil Engineering Division, Institution of Engineers, Bangladesh, ISSN 0379-4318, Vol. 29, No.2. pp. 187-206.

- Karim D.M. , M.J.B. Alam (1998) Air Travel Demand Model for Domestic Air Transportation in Bangladesh, Journal of Civil Engineering Division, Institution of Engineers, Bangladesh, ISSN 0379-4318, Vol. CE 26, No. 1 June 1998, pp 1-13

Conference Proceedings

- “Narrower Lanes, Safer Streets”, Annual Conference of CITE, Regina, Saskatchewan, July 2015.
- Karim D.M. , M.J.B. Alam (1998) Air Travel Demand Model for Domestic Air Transportattion in Bangladesh, Journal of Civil Engineering Division, Institution of Engineers, Bangladesh, ISSN 0379-4318, Vol. CE 26, No. 1 June 1998, pp 1-13.
- Karim D. M., A Model to Estimate Right Angle Accidents at Signalized Intersections, Proceedings of 6th Transportation Specialty CSCE Conference, Toronto, Ontario, Canada, June 2-4, 2005 (Presentation available in ZIP format).
- Karim D. M., Estimation of Vehicle-to-Vehicle Accident Risk at Signalized Intersections, Proceedings of the 40th CTRF (Canadian Transportation Research Forum) Annual Conference, Hamilton, Ontario, Canada, May 8-11, 2005, pp. 100-114 (Presentation available in ZIP format). In PDF.
- Karim D. M., Hitoshi IEDA, Shintaro Terabe., Modeling Angle Accident Risks at Four-legged Signalized Intersections and Its GIS Application, Proceedings of Infrastructure Planning, JSCE, No.24, CD-ROM, 2001.11, (Japanese).
- Hitoshi Ieda, Kiyoshi Takahashi, Shintaro Terabe, Ryuichi Shibasaki, Karim D. M., Risk Evaluation Model for Traffic Accident at Four-Legged Signalized Intersections, 37th Symposium for Infrastructure Planning, JSCE, Tsukuba, 2001, (Japanese).
- Karim D.M., H. Ieda and M.J.B. Alam (2000) Macroscopic Modeling for the Regional Air Travel Demand to Analyze the Potential of Hub-Spoke Air Transport System in South Asia, 9th World Conference on Transport Research, WCTR, Seoul, South Korea, 22-27 July, 2001.
- D.M. Karim, M.J.B. Alam, and M.M. Houqe (1999) Potential of Privatization of Domestic Air Transportation in Bangladesh, Procedinds of Civil and Environmental Engineering Conference, Asian Institute of Technology (AIT), 8-12 November, 1999.
- D.M. Karim, M.J.B. Alam (1999) A Demand and Cost Analysis of Civil Aviation in Bangladesh, Procedinds of the 26th, JSCE (Japan Society of Civil Engineering), 16-17th March, 1999.

PROFESIONAL COURSES

- Shared Multimodal Cities: Integrating Smart Mobility and City Planning for Livable Cities, EPIC, 2019.
- Rethinking Mobility Planning and Redesigning Cities for Innovative Mobility System, Ryerson University, 2017.Advanced Light-rail course for planner and engineers, EPIC, 2016.
- Road planning and design, Metro College, 2012-2014.
- Transportation and traffic engineering software training courses, Metro College, 2010-2014.

COURT APPEARANCES

- Qualified as an Expert Witness in Land-use Tribunal, Ontario Municipal Board for several projects for public agencies and on behalf of private consultant.

- Testified as an Expert Witness in Superior Court of Justice, Ontario (Toronto) for Winter Maintenance and Temporary Conditions: Summary judgement Trial- Hilda Fernandez vs. City of Toronto, TTC & Bondfield, 2020.
- Testified as an Expert Witness in Superior Court of Justice, Ontario (Ottawa) for Winter Maintenance in private property: Court Trial - Musa v. Carleton Condominium Corporation No. 255 et al., 2022 ONSC 1030, October 2021.
- Testified as an Expert Witness in Superior Court of Justice, Ontario (Woodstock): Court Trial - Permanent Paving ats Voisin, May 2022.

APPENDIX B: LIST OF PROVIDED MATERIALS

List of Provided Materials

- Principal Design and Maintenance Standards, Guidelines and General Practices for Ontario Highways report prepared for the Red Hill Valley Parkway Inquiry ('RHVPI') by Mr. Russell Brownlee of True North Safety Group, dated March 9, 2022;
- Primer on Friction, Friction Management, and Stone Matrix Asphalt Mixtures report prepared for the RHVPI by Mr. Gerardo W. Flintsch of FM Consultants, dated March 2022;
- Highway Design and Assessment Report prepared for the RHVPI by Mr. Brownlee of True North Safety Group, dated November 1, 2022;
- Analysis of Friction on the RHVP report prepared for the RHVPI by Mr. Flintsch of FM Consultants, dated November 2022;
- Red Hill Valley Parkway Inquiry Overview Documents:
  - No. 1: Introduction;
  - No. 2: City of Hamilton Governance and Structure;
  - No. 3: Construction of the Red Hill Valley Parkway (RHVP);
  - No. 3.1: RHVP Design and Geometry;
  - No. 4: The Ministry of Transportation and Friction Testing;
  - No. 5: RHVP 2008 to 2012 and City Road Safety Initiatives 2008 to 2018;
  - No. 6: The 2013 CIMA Report and the 2013 Golder and Tradewind Reports;
  - No. 7: The 2015 CIMA Report;
  - No. 8: 2017 Pavement Evaluation and RHVP-related Safety Initiatives;
  - No. 9: Events Leading to the Discovery and Disclosure of the Tradewind Report;
  - No. 10: Disclosure of the Tradewind Report to Council and Public; and
  - Terms of Reference.
- Mountain East–West and North–South Transportation Corridor, Environment Assessment Submission Volume I, produced by the Regional Municipality of Hamilton-Wentworth, dated December 1982;
- Mountain East–West and North–South Transportation Corridor, Environment Assessment Submission Volume II – Exhibits, produced by the Regional Municipality of Hamilton-Wentworth, dated December 1982;
- Preliminary Design Report, dated January 31, 1990;
- Red Hill Valley Project Design Report – Section 1 (Introduction), draft, dated January 2006;
- Red Hill Valley Project Design Report – Section 2 (Engineering Design), draft, dated January 2006;
- Red Hill Creek Expressway Preliminary Design Report, draft, dated November 2003;

- Technical Memorandum No. 2, titled Impact Assessment of Alternatives, by McCormick Rankin, dated July 1994;
- Four City of Hamilton Annual Collision Reports, for the years of 2017, 2018, 2019, and 2020;
- Hamilton Public Works Department RHVP drawings:
    - Part A – Mud Street Interchange to South of Greenhill Avenue;
    - Part B – South of Greenhill Avenue to Queenston Road;
    - Part C – Queenston Road to QEW Interchange; and
    - Part D – Mud Street Interchange to QEW Interchange.
- Twenty-three spreadsheets of friction data;
- Countermeasures Memo – 2013 and 2015, dated January 14, 2022;
- RHVP Inquiry – Brief of CIMA Reports;
- RHVP Inquiry – Brief of Council Reports;
- RHVP Inquiry – Brief of Golder Reports;
- RHVP Inquiry – Final Overview Document;
- Summary of Friction Testing: Testing Data;
- Summary of Friction Testing spreadsheet;
- Traffic volume data for the RHVP, 227 files, dated from 2007 to 2019;
- Ramp volume data for the RHVP, 28 files, dated September 11 to 14, 2019;
- Database file of RHVP traffic volumes;
- Documents relied upon by Mr. Flintsch in the FM Global reports;
- Documents relied upon by Mr. Brownlee in the True North Safety reports;
- Appendix B – Karim Report: Issues and Anticipated Evidence, dated December 7, 2022; and
- Spreadsheet of mainline collision data for the RHVP and Lincoln Alexander Parkway, dated 2008 to 2021.

APPENDIX C: BRIEF OUTLINE OF THE INITIAL RHVP PLANNING AND DESIGN PROCESS

Appendix C: Brief Outline of the Initial RHVP Planning and Design Process

The planning and design of the RHVP went through several processes from 1982 until its completion in 2007. This appendix briefly summarizes key highlights from these documents that were produced over three decades of planning and design processes which underlay the assumptions and background information for this report.

1.1.1 1982 Environmental Review

An "Environment Assessment Submission," dated December 1982 (the '1982 EA study'), was submitted by the Regional Municipality of Hamilton-Wentworth to initiate the planning process of the RHVP. Key highlights from the report were:

- The report identified several environmentally constrained areas (Figure 1) along the proposed alignment of the RHVP. The term "*environmental constraint areas*" had been selected to encompass:
    - *i)* *"those areas of particular sensitivity to impacts of construction on soils, groundwater, and surface waters; and*
    - *ii)* *those areas of provincial, regional or local significance for their geological or topographical formations, their vegetation communities, and their wildlife populations."*
- These environmental constraints typically become key considerations for selecting alignment and design elements that would minimize environmental impacts when the highway is built.
- Based on the analysis undertaken on the impact on social, natural, and environment conditions, several adjustments in the highway alignment were carried out to minimize the disturbance of the terrestrial and aquatic ecosystems. Fourteen areas of concern relative to the natural environment were identified at the microscale. As a result of the interactive process, five of the features were completely avoided. Of the remaining areas, the impact on all but two was considered moderate and capable of successful mitigation.
- The report identified that the impact on the Red Hill Creek Marsh would be severe and difficult to mitigate. In assessing the significance, the impact must be viewed in relation to the existence and planned expansion of the Queen Elizabeth Way (the 'QEW') between Burlington Street and Highway 20. At the time of the assessment, the marsh area was highly disturbed as a result of being adjacent to the QEW and the past construction of the hydro transmission towers and the Canadian National Railway spur line to Lang's Foods.

- Based on recently available safety trend statistics during the study periods and City of Hamilton statistics, the indices of the potential relative collision rate and severity of vehicle accidents were prepared. For freeways, a potential collision rate of 1.0 per million vehicle kilometres is representative of provincial freeways. For major controlled-access roadways, a potential collision rate of 2.0 is representative compared to a potential collision rate of 5.0 for uncontrolled-access urban arterials.[1] The potential collision rate per million vehicle kilometres was estimated considering the mix of freeway and arterial components within each alternative.
- The Roads and Transportation Association of Canada ('RTAC') design standards[2] were used for the project. Allowances were made in the highway's grading to ensure that the initial four lane urban arterial could be expanded to a four-lane urban freeway should it be warranted in the future. Consequently, the mainline horizontal and vertical alignment conformed to urban freeway standards with a design speed of 100 km/h. Figure 2 lists the design criteria for urban freeways with a design speed of 100 km/h.

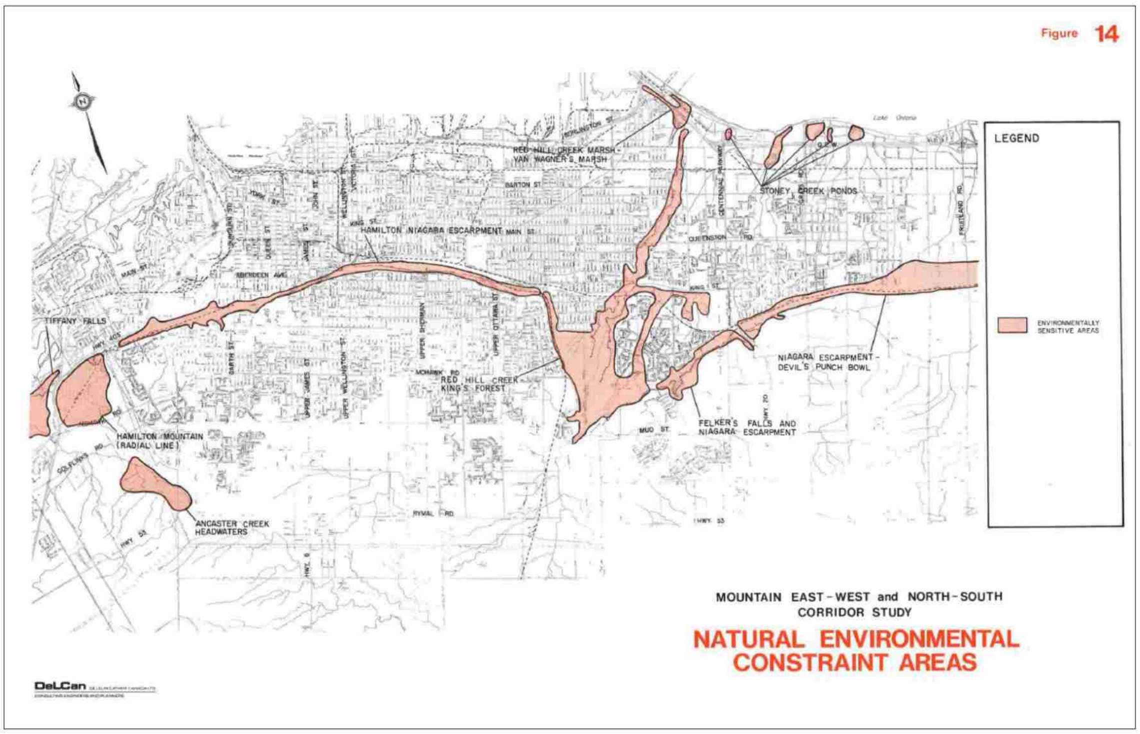

Figure 1: Identified natural environmental constraint areas (Source: 1982 EA study).

[1] Environmental Assessment Submission. (1982). Section 5.4.2, Page 5-42.
[2] The 7th editions of these standards were published between 1985 and 1988.

Table 6.1
SELECTED DESIGN CRITERIA

North-South Parkway

Classification				- Divided Urban Freeway
Design Speed				- 100 km/h
Superelevation (e max)				- 0.06 m/m
Horizontal Curve				- 420 min.
Lane Width				- 3.75
Grade -	Min.			- 0.30%
-	Max.			- 5.0%
Vertical Curve	- Sag -		Min. K	- 50
	- Crest -		Min. K	- 70
			Des. K	- 110
Side Slopes -	Cut			- 3:1
-	Fill			- 3:1 in Heights of Fill 1.2 m or less 2:1 in Heights of Fill Over 1.2 m
Back Slopes -	Cut			- 2:1 max (3:1 at Berm)

Figure 2: Selected design criteria for urban freeways with a design speed of 100 km/h (Source: 1982 EA study).

1.1.2 1990 Preliminary Design Report

Following the completion of the initial environmental studies, the initial preliminary design began in 1988 and was completed in 1990. A preliminary design report was prepared in January 1990 (the '1990 PDR'). Subsequent preliminary design in several stages continued until 2006. Key highlights from this report were:

- The engineering investigations were developed from the functional plans and database of the initial 1982 EA report.
- The report noted using the "*MTO design standard*"[3] to develop a preliminary design for the RHVP. The 1990 PDR refined the RHVP's alignment and established locations of interchanges using design standards that were suitable for urban highways (Figure 3).
- Several design alternatives were developed and published in the "Impact of Alternative Assessment" tech memo, dated July 1994.

[3] Ministry of Transportation of Ontario. (1985). *Geometric Design Standards for Ontario Highways* (the '1985 MTO design guide').

- The revision of the original 1990 PDR was completed in November 2003, which became a supplement to the 1990 PDR "*to be read in conjunction with 1990 PDR*." The November 2003 supplement to the PDR dealt mostly with engineering design features.
- A further revision of the PDR was completed in January 2006, citing design criteria confirming to MTO's Geometric Design Manual and Ontario Provincial Standard Drawings (OPSD) for the design of roadways and structures.

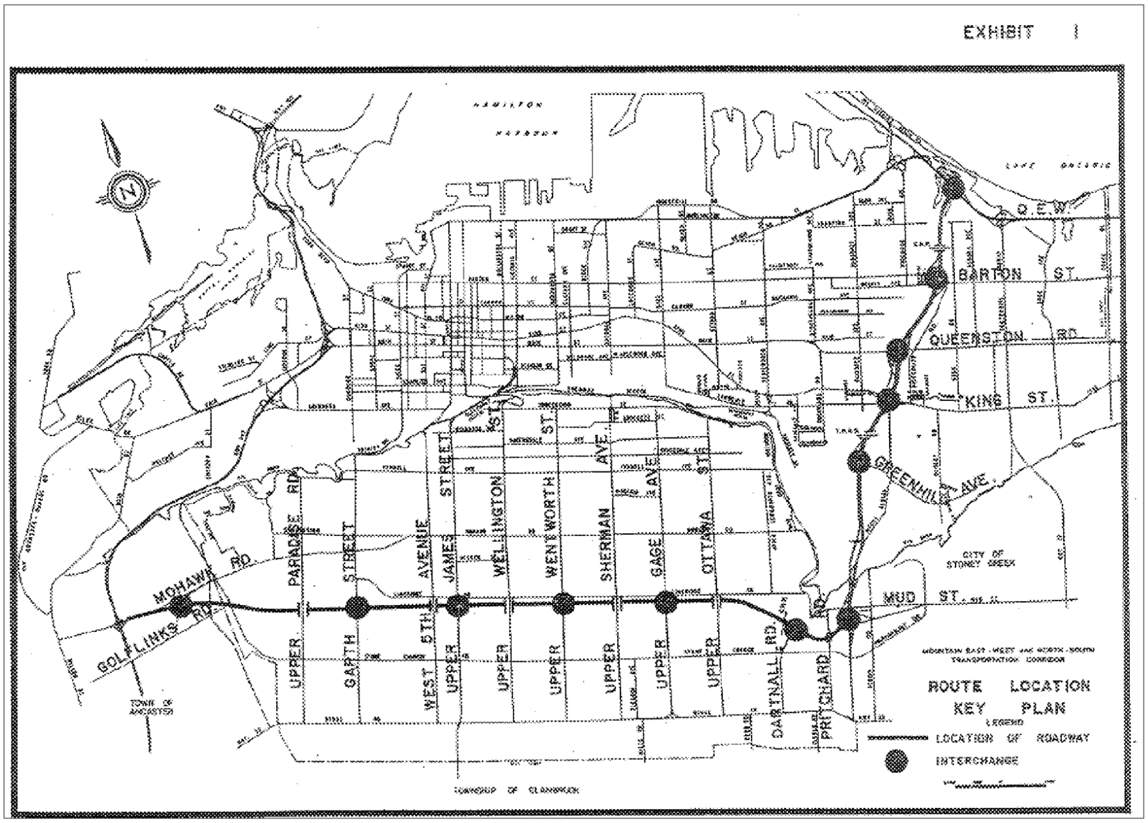

Figure 3: Proposed preliminary design and interchange locations (Source: 1990 PDR).

1.1.3 2003 Preliminary Design Report

After the completion of the initial round of preliminary designs, the second major revision to the design report was completed in 2003 (the '2003 PDR'). Key highlights from this report were:

- This PDR documented details of those components of the north–south section of the Red Hill Creek Parkway that can be found in the extensive Impact Assessment Design Process (IADP) reports.
- Section 2.2 stated that a southbound truck-climbing lane was required, as the grade through the escarpment was 4%, reducing the speed of a typical truck to 35 km/h (using the Transportation Association of Canada ('TAC') guideline).[4]

[4] Geometric Design Guideline for Canadians Roads. (1999). Transportation Association of Canada.

- The design of the proposed interchanges had been changed to improve traffic operations or environmental features, and/or to accommodate the relocation of the Red Hill Creek and Red Hill Valley trails.
- Only partial illumination would be provided, i.e., only at decision points such as noses at interchange ramps and City streets. The illumination would be designed according to Illuminating Engineering Society of North America (IESNA) and Provincial standards, and City requirements.

1.1.4 2006 Preliminary Design Report

After the completion of the initial round of preliminary designs, the final design report was completed in 2006 (the '2006 PDR'). Key highlights were from this report:

- This PDR detailed mitigation strategies and plans for construction and post construction monitoring to address environmental impacts identified during the initial planning stage.
- The preliminary design of the north–south section was provided in detail in this report, while the QEW section that was being designed by the MTO was documented in a separate PDR. Selected design criteria were listed in a table, reproduced as Figure 4.
- The east–west section, renamed the LINC, was opened to motor vehicle traffic in October 1997.
- Roadway design criteria conforming to those in the MTO design guide had been adopted for this highway project. The OPSD and Ontario Provincial Standard Specifications (OPSS) would be used as a guide for the design of roadways and structures.
- Six bridge structures were proposed in the north–south corridor.

TABLE 2.1

DESIGN CRITERIA
PRITCHARD ROAD TO BRAMPTON STREET
(STA. 10+500 TO STA.29+120)

	Design Standards	**Proposed Standards**
Highway Classification	RFD 100	RFD 100
Minimum Stopping Sight Distance	185	185
Super-elevation (e max)	0.06	0.06
Grades - minimum (desirable)	0.5	0.5
- maximum - upgrade	4.0%	4.0%
- downgrade		
Minimum "K" factor - crest	70	70
- sag	45	45
Minimum radius	420	420
Pavement width	2 x 7.5	2 x 7.5
Shoulder width (paved)	3.0R/2.5L	3.0R/2.5L
Shoulder rounding	1.0	1.0
Truck climbing lane	3.5	3.5
Ramp width - 1 lane	4.75	4.75
- 2 lanes	7.5	7.5
Median width		8.5
R.O.W. width		varies
Posted Speed	90	90
Vertical clearance for bridges over roadways (OHBDC) – solid cast in pace concrete bridges	4.65	4.65
Vertical clearance for bridges over roadways		

January 31, 2006

Figure 4: Selected design criteria (Source: 2006 PDR).

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Vancouver	(604) 674-1100
Calgary	(403) 208-4545
Toronto	(416) 368-1700
Ottawa	(613) 903-6900

30fe.com