Engineering Evaluation of Traffic Signal Timing

Roar File Number: 17R06031 **Date:** July 20, 2017

Prepared For:

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Attention: Mr. Robert L. Zaparniuk

Loss Location: Bishop Grandin Boulevard & River Road, Winnipeg, Manitoba

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1.0 INTRODUCTION

It was reported that, on October 16, 2015, Mr. Jim Aisaican-Chase was travelling westbound on Bishop Grandin Boulevard near its intersection with River Road. As he approached the intersection the traffic light he was facing changed from Green to Yellow. Mr. Aisaican-Chase continued through the intersection at a constant speed of 80 km/h, and was issued a violation for entering the intersection facing a Red traffic signal.

It is understood that, within the City of Winnipeg, all Yellow traffic signals had a duration of 4.0 seconds. This was the case at all signalized intersections. The posted speed limit range for intersections in Winnipeg was reportedly between 40 km/h and 80 km/h. The intersection at Bishop Grandin Boulevard & River Road had a posted speed limit of 80 km/h and was equipped with a Red light camera.

On June 19, 2017, Roar Engineering was retained to conduct an independent assessment of Mr. Aisaican-Chase's traffic violation. Specifically, Roar Engineering was asked to comment on the appropriateness of a 4.0 second Yellow traffic signal duration, and whether or not Mr. Aisaican-Chase's decision to proceed through the traffic signal was reasonable under the circumstances.

The following analysis is based on a review of the provided materials in Appendix A. Please note that, throughout the literature and provided documents, the terms 'Yellow' and 'Amber' are used interchangeably, and have the same meaning. The author uses the terms 'Green', 'Yellow', and 'Red' to refer to the three basic traffic signal phases.

2.0 QUALIFICATIONS OF THE AUTHOR

Mr. Darryl Schnarr has practiced Forensic Engineering for over six years, primarily engaged in the investigation and reconstruction of vehicle collisions. These investigations have included the evaluation of roadway design, traffic signal timing, and the safety implications of incorrect roadway design and signal timing.

Mr. Schnarr graduated from University of Waterloo's Faculty of Engineering, is a licensed Professional Engineer, and is a member of the Institute of Transportation Engineers (ITE). He has also been qualified as an expert witness in both the Ontario Court of Justice and the Ontario Superior Court of Justice. A copy of Mr. Schnarr's Curriculum Vitae has been enclosed as Appendix B.

3.0 OBSERVATIONS

3.1 THE INTERSECTION

It was reported that, within the City of Winnipeg, all signalized intersections had an identical Yellow traffic signal duration of 4.0 seconds. The intersection at which Mr. Aisaican-Chase's violation occurred was Bishop Grandin Boulevard & River Road. This intersection existed within the southern portion of Winnipeg, east of the Red River. Both eastbound and westbound traffic on Bishop Grandin Boulevard were controlled by traffic signals. The posted speed limit on Bishop Grandin Boulevard was 80 km/h. Figure 1 depicts a map of the area surrounding the intersection. Figure 2 depicts an overhead view of the intersection.

Figure 1: Map of the Area of the Intersection of Bishop Grandin Boulevard & River Road.

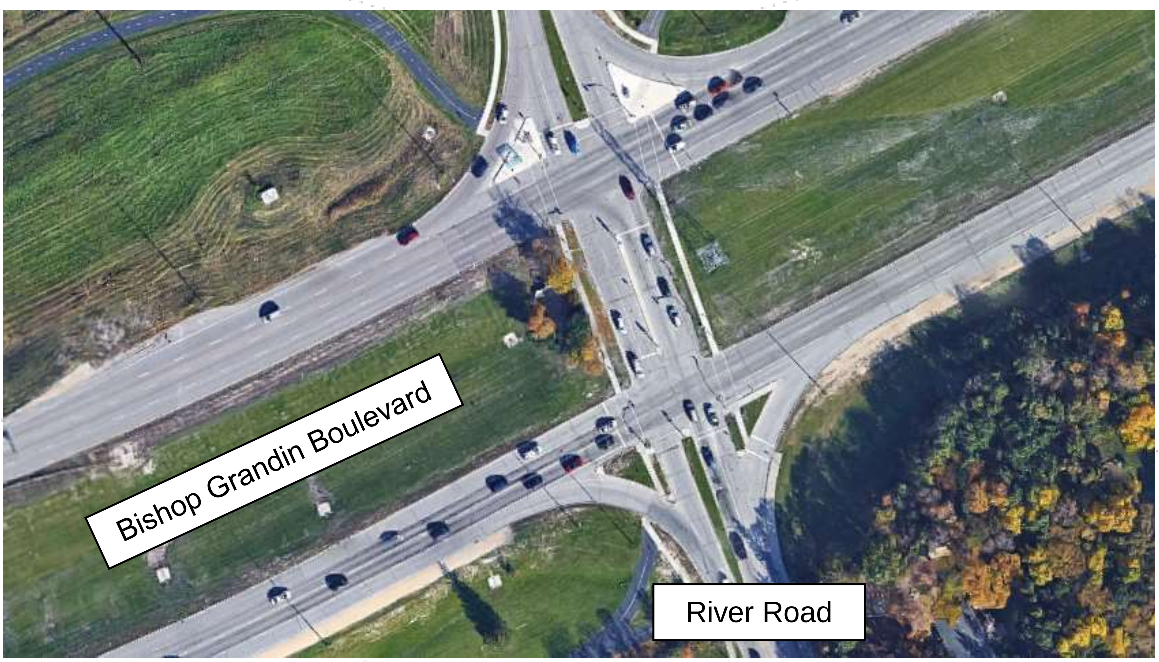

Figure 2: Overhead View of the Intersection of Bishop Grandin Boulevard & River Road.

3.2 RED LIGHT VIOLATIONS

As a result of a Freedom of Information Act request, data related to the number of violations issued at the intersection of Bishop Grandin Boulevard & River Road were obtained. This data indicates that 1661 violations were issued in 2015, while 1856 violations were issued in 2016. No violations were issued to traffic entering the intersection 0.1 seconds or less after the start of the Red traffic signal phase. The largest segment of violations were issued to traffic entering the intersection between 0.1 and 0.2 seconds after the start of the Red traffic signal phase. The data related to how long after the traffic signal turned Red is summarized in Figure 3 below.

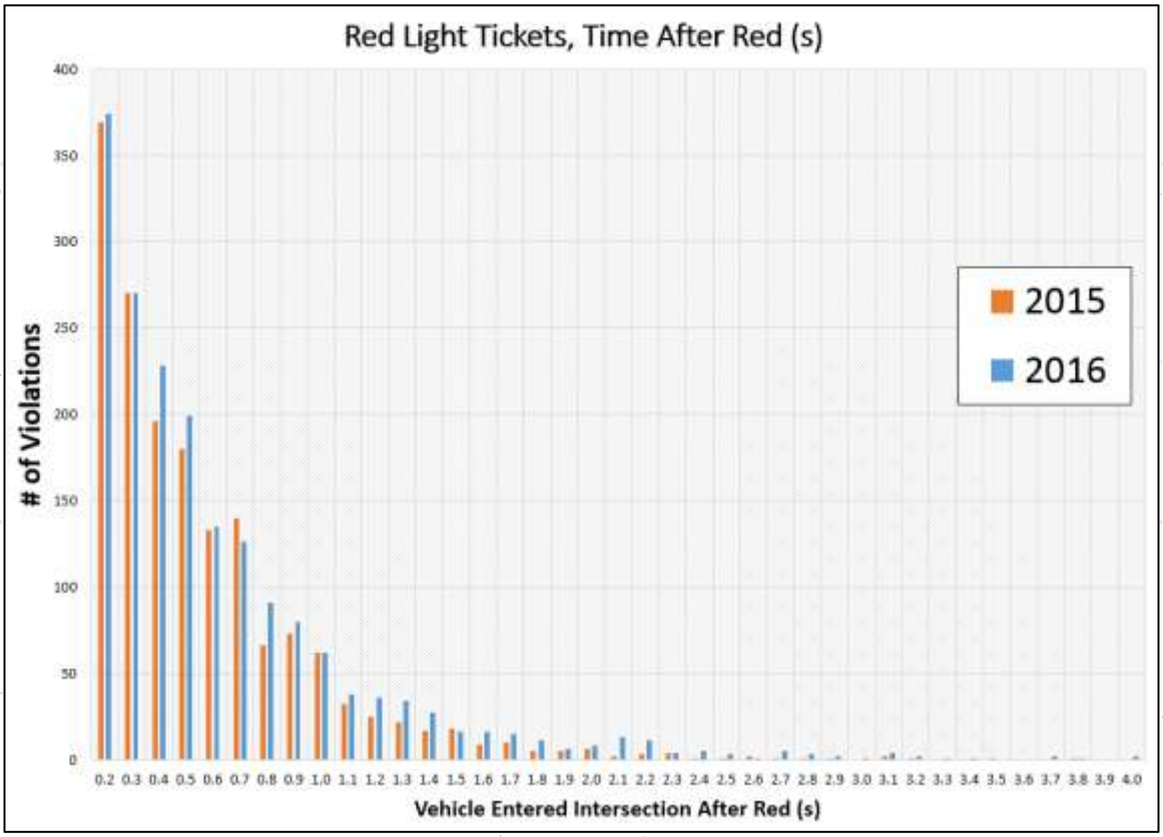

Figure 3: Graph of Red Light Violations in 2015, 2016 on Bishop Grandin Boulevard & River Road.

Data for 32 intersections with Posted Speed Limits ranging from 50 km/h to 80 km/h for the first four months of 2016 were provided, and are discussed in Section 6.5.

4.0 REPORTED CIRCUMSTANCES

4.1 EVIDENCE OF MR. JIM AISAICAN-CHASE

Evidence from Mr. Aisaican-Chase was included as part of the proceedings at trial, dated April 26th, 2017.

Mr. Aisaican-Chase stated that he was travelling westbound on Bishop Grandin Boulevard in his 2000 Volkswagen Golf (the "Aisaican-Chase Volkswagen") when he observed the traffic signal change from Green to Yellow. He was travelling 80 km/h when the traffic signal changed. He stated that he believed he had enough time to clear the intersection, and as such, did not apply the brakes or accelerate as his vehicle approached the intersection. He stated that he was surprised when he observed the traffic signal change from Yellow to Red. Had he applied the brakes immediately after seeing the traffic signal change to Yellow, he believes he would not have stopped until after he entered the intersection. It was his opinion that his decision to continue travelling at a constant speed was the safest act at that moment.

Mr. Aisaican-Chase stated that his Volkswagen was in good mechanical condition at the time of the incident, with the exception of a non-functioning radio.

5.0 Analysis and Discussion

In order to evaluate the reasonableness of Mr. Aisaican-Chase's decision to proceed through the intersection, the appropriateness of the current Yellow traffic signal duration must be evaluated. To facilitate this evaluation, an independent determination of the Yellow traffic signal duration was conducted. The following sections describe the method by which this determination was made.

5.1 Definitions

Yellow Traffic Signal Duration – Also referred to as the 'Yellow Change Interval', this is the time duration after the Green traffic signal changes to Yellow, prior to it changing to Red. The purpose of a Yellow traffic signal is to communicate to oncoming traffic that the Green signal phase has ended, and that a Red traffic signal will be exhibited immediately thereafter. As discussed in Section 1.0, the terms 'Yellow' and 'Amber' are used interchangeably in both the provided documents and the literature on the topic.

Red Clearance Interval – Also referred to as the 'All Red' phase, this is the time duration after the Yellow signal phase ends, before the perpendicular Green signal begins. The purpose of the Red clearance interval is to allow vehicles which enter the intersection in the last moments of the Yellow phase to travel through the intersection and exit on the other side prior to allowing perpendicular traffic through.

Permissive Yellow – The term Permissive Yellow is used when determining whether or not an intersection violation has occurred. Within a Permissive Yellow jurisdiction, vehicles are permitted to enter an intersection (that is, the front of their vehicle is permitted to cross the stop bar) during any portion of the Yellow traffic signal phase. If a vehicle enters an intersection during the Red traffic signal phase, a violation has occurred. It is understood that Red light violations at the intersection of Bishop Grandin Boulevard & River Road were issued based on the Permissive Yellow definition.

Restrictive Yellow – The term Restrictive Yellow is also used when determining whether or not an intersection violation has occurred. Within a Restrictive Yellow jurisdiction, vehicles are required to exit the intersection (that is, the rear of their vehicle must cross through the intersection completely) prior to the commencement of the Red traffic signal phase. If a vehicle does not exit the intersection prior to the start of the Red traffic signal phase, a violation has occurred.

5.2 THE ITE YELLOW CHANGE INTERVAL FORMULA

The Institute of Transportation Engineers (ITE), founded in 1930, is an international membership association of transportation professionals who work to improve mobility and safety for all transportation system users. The ITE is not a regulatory body, and as such, none of the recommendations made by the ITE are laws. However, the ITE works with organizations such as the U.S. Department of Transportation to develop traffic regulations which become mandatory. The ITE also publishes papers on transportation topics, including the subject of traffic signal durations.

In Canada, the CITE includes more than 2,000 transportation engineers, planners, technologists, and students across the county, including a Manitoba Chapter.

The subject of Yellow traffic signal durations was first discussed in a peer-reviewed publication by Gazis et al in 1960 in a paper titled "The Problem of the Amber Signal Light in Traffic Flow[1]". Based in part on this publication, the ITE published their first Yellow Change Interval Formula in 1965 in the third edition of their Traffic Engineering Handbook[2]. In 1982, this formula was modified to account for the effect of gravity on a vehicle travelling up or down a grade[3]. This ITE formula is widely used when determining

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[1] Gazis, Herman, Maradudin, GM Research Labs ***The Problem of the Amber Signal Light in Traffic Flow***, Institute for Operations Research and the Management Sciences, Vol 8, No. 1 (1960).
[2] Institute of Traffic Engineers, ***Traffic Engineering Handbook, 3rd Edition***, Institute of Traffic Engineers, Washington DC, **101** (1965)
[3] Institute of Traffic Engineers, ***Manual of Traffic Signal Design,*** (1982)

the durations of Yellow traffic signal durations. A separate ITE formula is used to calculate Red clearance intervals. That calculation is outside of the scope of this report.

The Yellow traffic signal duration formula recommended by the ITE Traffic Engineering Handbook is reproduced as Figure 4 below.

$$Y(v) = T_{pr} + \frac{V_a}{2d_r + 2gG_r}$$

where:

$Y(v)$ = yellow interval evaluated at speed $V_a = v$, s;
d_r = deceleration rate, use 10 ft/s^2;
g = gravitational acceleration, use 32.2 ft/s^2;
G_r = approach grade, ft/ft;
T_{pr} = driver perception-reaction time, use 1.0 s; and
V_a = speed of vehicle approaching the intersection (typically the 85th percentile speed), ft/s.

Figure 4: The ITE Yellow Traffic Signal Duration Formula.

The ITE Yellow traffic signal duration formula was derived from a basic set of kinematic equations. Kinematics is the study of bodies or systems of bodies in motion, and is used by engineers in a variety of subjects, vehicular motion among them. The calculation of stopping distance, stopping time, and vehicle speeds during acceleration or braking are all completed using the kinematics equations.

The output of this formula, Y(v), represents the ITE's recommended Yellow traffic signal duration. There is one constant value in this formula, g, which represents the gravitational acceleration here on Earth. There are four variables within this formula, velocity (v), driver perception and response time (T_{pr}), deceleration rate (d_r), and the grade of the road upon approach (G_r). The following sections describe each variable, the literature related to that variable, the recommended value, and the reasoning behind recommending that value.

5.2.1 VELOCITY (V)

The first factor to be evaluated when determining traffic signal timing is the vehicle approach velocity (often referred to as speed). However, there are several definitions of the word 'speed'. The first, and most obvious, is the 'Posted Speed Limit'. The Posted Speed Limit is the maximum speed permitted by law on a given roadway. It is widely accepted, however, that traffic does not all travel at an identical speed. Speed exists as a distribution. Studies indicate that traffic travels at a speed above the Posted Speed Limit. One such study, authored by Hoogendoorn[4] et al, estimated the speed distribution of vehicles travelling 100 km/h (62.1 mph, 27.8 m/s) along a freeway. The study, unsurprisingly, reported that fewer than 50% of drivers, independent of lane position, travel at or below the Posted Speed Limit. Figure 5 below depicts two such speed distributions.

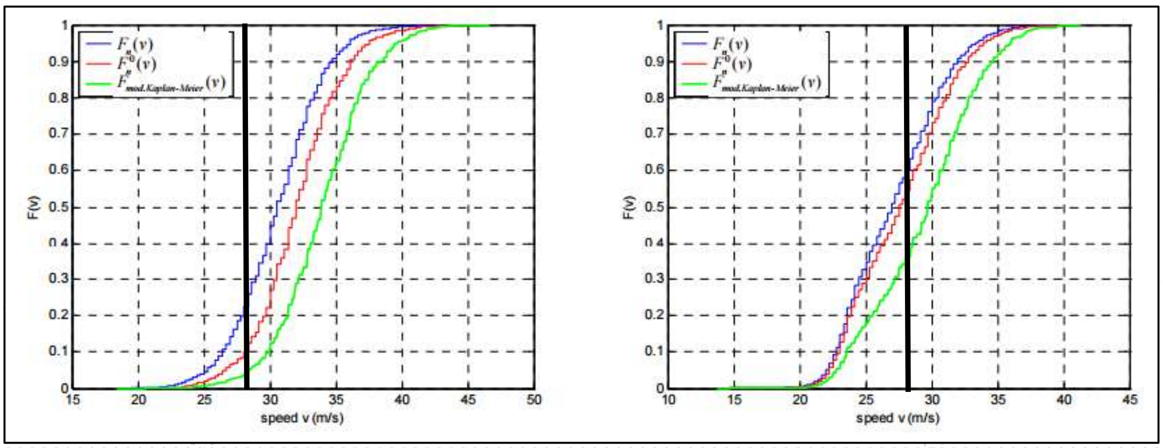

Figure 5: Distribution of Vehicle Speeds in Left Lane (left) and Right Lane (right) in a posted 100 km/h speed zone. Vertical line at speed limit added for clarity.

Traffic engineers are well aware of this, and use the term 'Design Speed' to account for this distribution of vehicle speeds. According to the ITE Traffic Engineering Handbook, the American Association of State Highway and Transportation Officials (AASHTO) Policy

[4] Hoogendoorn, S.P. (2005b). ***Vehicle-type and lane-specific free speed distributions on motorways: a novel estimation approach using censored observations*** Transportation Research Record. pp. 148-156.

on Geometric Design of Highways and Streets[5], NCHRP Report 731[6], and NCHRP Report 504[7], this 'Design Speed' is defined as the 85th percentile speed of drivers on a particular roadway. The logic behind using the 85th percentile fastest driver is to ensure that the roadway features (such as road curvature, stopping sight distance, traffic signal durations, etc.) are adequate for the speeds the public is actually travelling. NCHRP Report 504 reported that there is a "strong relationship between operating speed, or the 85th percentile speed, and the posted speed limit." The report concludes that "the 85th percentile speed is approximately 7 miles per hour greater than the posted speed limit". Therefore, in the absence of a traffic speed survey, NCHRP Report 504 recommends that 7 mph (11.2 km/h) be added to the Posted Speed Limit to arrive at the Design Speed. In Canada, 10 km/h is traditionally added to the Posted Speed Limit in order to keep the numbers round and keep tabulated data simple.

NCHRP Report 504 states that their data "applied to roadway sections and not necessarily to intersection approaches." However, there is no published evidence that drivers approach intersections at a lower speed than they travel along a roadway section. This is consistent with the author's experience investigating hundreds of vehicle collisions, many of which occurred at or within intersections. The ITE Traffic Engineering Handbook agrees, and recommends using Design Speed rather than Posted Speed Limit for calculations related to roadway use. This includes traffic signal timing.

While the speeds of vehicles approaching an intersection is a distribution, it is recommended that, for the purposes of roadway calculations, a Design Speed approximately 10 km/h faster than the Posted Speed Limit be used.

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[5] American Association of State Highway and Transportation Officials, ***A Policy on Geometric Design of Highways and Streets,*** (2001).

[6] H. McGee Sr., K. Moriarty, K. Eccles, and M. Liu. ***Guidelines for Timing Yellow and All-Red Intervals at Signalized Intersections.*** National Cooperative Highway Research Program Report 731. Transportation Research Board, 2012.

[7] Fitzpatrick, K., P. Carlson, M.A. Brewer, M.D. Wooldridge, and S. Miaou. ***Design Speed, Operating Speed, and Posted Speed Practices.*** National Cooperative Highway Research Program Report 504. Transportation Research Board, 2003.

5.2.2 PERCEPTION & RESPONSE TIME (T_{PR})

Drivers approaching a Green traffic signal that changes to Yellow require an amount of time to perceive the traffic signal change and respond to that change. This interval is referred to as the Perception and Response Time (PRT). PRT includes four main components: Detection, Identification, Decision, and Response[8]. In the case of a driver responding to a changing traffic signal by coming to a stop, the PRT is measured from the moment the traffic signal changes to the moment the brakes are applied.

Each driver approaching the same intersection will perceive and respond to a changing traffic signal over a different time interval. Therefore, a distribution of PRTs exist for drivers responding to changing traffic signals. Olson & Sivak[9] studied the amount of time required for a driver to perceive and respond to an unexpected hazard in daylight conditions. Figure 6 below represents the distribution of PRTs.

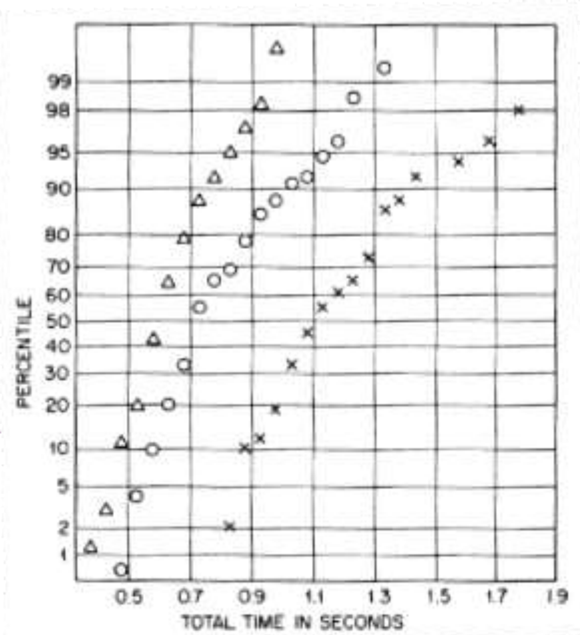

Figure 6: Distribution of Total PRT for Young Subjects (X = Surprise, O = Alerted, Δ = Brake).

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[8] P. Olson and R. Dewar. ***Human Factors in Traffic Safety, Second Edition.*** Lawyers and Judges Publishing Company. 2007.
[9] P. Olson and M. Sivak. ***Perception-Response Time to Unexpected Roadway Hazards.*** The Human Factors Society. 1986, 28(1), 91-96.

Olson & Sivak's findings indicate that 95% of young subjects responded to an unexpected hazard in 1.6 seconds or less. However, not all drivers can be described as 'young subjects'. Alternatively, it is reasonable that a traffic signal changing from Green to Yellow may be somewhat less than a surprise.

The ITE Traffic Engineering Handbook recommends using a 1.0 second PRT, which was based on the work of Gazis et al. Gazis' team observed 87 subjects braking in response to traffic signals changing from Green to Yellow, and recorded the distribution of responses. They concluded that "the mean delay time was found to be 1.14 seconds." Figure 7 below depicts the histogram of Gazis' data.

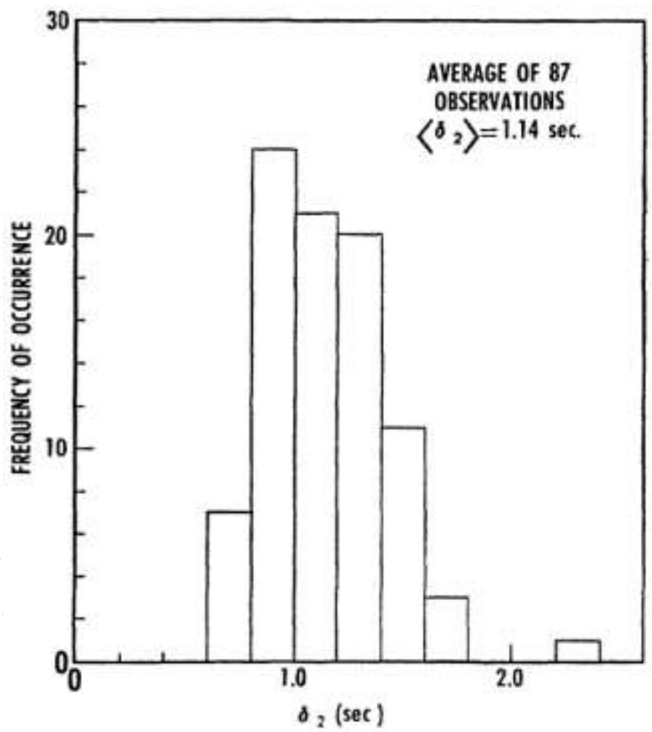

Figure 7: Distribution of Total PRT for Changing Traffic Signal.

Though no standard deviation for Gazis' data was included in the study, it is clear that more vehicles operators required more than 1.0 seconds than required less than 1.0 seconds. The 85th percentile appears to be somewhere in the vicinity of 1.5 seconds. In addition, Gazis did not obtain demographic information for the drivers he surveyed.

Demographics of drivers, including age, exist as a distribution. Olson & Dewar concluded that drivers aged 65 – 69 respond slower than drivers aged 25 – 40, with drivers aged 70+ responding slower yet. When deciding the appropriate PRT, the age of drivers in the area should be considered. There is no information available at this time which indicates that the population in the City of Winnipeg is older or younger than the average.

While the PRTs of drivers responding to a traffic signal changing from Green to Yellow is a distribution and not a single value, studies recommend that a minimum of 1.0 seconds should be provided for the perception of and the response to this changing traffic signal. If the traffic engineer responsible for the intersection desires an additional level of safety, PRTs of up to 1.5 seconds are recommended.

5.2.3 Deceleration Rate (D_R)

After a driver perceives a traffic signal which has changed from Green to Yellow and decides to respond by braking to a stop prior to entering the intersection, that driver must slow their vehicle by braking. The rate at which this braking occurs is referred to as the deceleration rate. Deceleration rate is a function of the friction between the tires and roadway, as well as the force with which the brake pedal is pressed.

Braking to a stop in response to a changing traffic signal should not be an emergency manoeuvre, rather a controlled and safe procedure, similar to stopping for a stop sign. Therefore, the deceleration rate applied should be possible, safe, and comfortable.

Weather in Canada, and specifically in Winnipeg, is highly variable. The roadway conditions range from warm/dry to cold/icy within the span of each year. The deceleration rate assumed must be reasonable in most weather conditions. During the winter, the presence of ice and snow on the roadway, as well as the cold temperatures, reduces the available friction between the tires and the roadway. Decelerating at a high rate in these poor roadway conditions can lead to wheel lock-up and loss of vehicular control. As such, the deceleration rate assumed must take roadway conditions into consideration. A study by Martin & Schaefer[10] indicated that the deceleration rate available on snow and ice ranges between 3.86 – 12.5 ft/s^2 (0.12 – 0.39 g[11]). The availability of traction is one consideration when determining a reasonable deceleration rate.

As drivers approach a Yellow traffic signal and brake to a stop, they brake at different rates. A distribution of deceleration rates of drivers is presented in NCHRP Report 731. In general, approximately 50% of these drivers were found to decelerate at a rate of 10 ft/s^2 or less. Figure 8 depicts this distribution of deceleration rates.

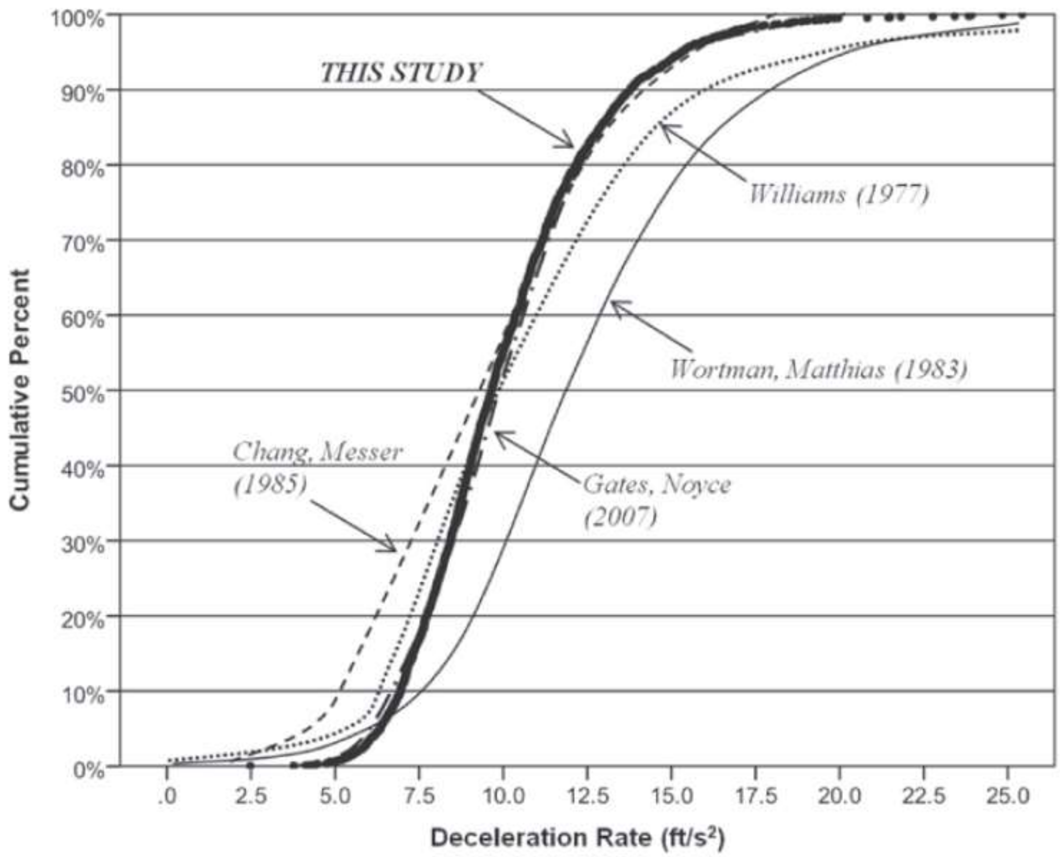

Figure 8: Distribution of Deceleration Rates for First-to-Stop Vehicles.

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[10] Martin, D., Schaefer, G., ***Tire-Road Friction in Winter Conditions for Accident Reconstruction.*** Society of Automotive Engineers, Paper #960657. 1996.
[11] Where 1 'g' is the acceleration of an object due to gravity. 0.12g represents a speed change of approximately 4 km/h every second, while 0.39g represents a speed change of approximately 13 km/h every second.

A study by Hugemann[12] had similar results. Hugemann and his team studied the everyday braking decelerations carried out by normal drivers carrying out “planned” stops. His team found that the 10th / 50th / 90th percentile drivers decelerated at rates of 1.3 / 2.2 / 3.3 m/s^2 (4.3 / 7.2 / 10.8 ft/s^2) respectively. This finding indicates that, when approaching a planned, non-emergency stop such as a traffic signal or stop sign, drivers decelerate at the low end of the range outlined previously in NCHRP Report 731.

It is the traffic engineer’s job to determine what deceleration rate to use which creates a possible, safe, and comfortable deceleration toward an intersection. The ITE Traffic Engineering Handbook recommends using 10 ft/s^2 which represents the median (50th percentile) deceleration rate based on the studies by Gazis and others. There is an argument to be made that 10 ft/s^2 is too high, as evidenced by Hugemann. Further, it is prudent to consider using an 85th percentile slow deceleration rate to include the behaviour of a larger percentage of the population. At this time, based on the information available, it is the author’s recommendation that 10 ft/s^2 be used in Yellow traffic signal duration calculations.

5.2.4 Approach Grade (Gr)

The grade of the roadway approaching an intersection impacts the ability for a vehicle to decelerate. Gravity acts downhill at all times, resulting in a more rapid deceleration when travelling uphill, and a less rapid deceleration when travelling downhill. A graphical representation of this phenomenon is presented as Figure 9. Because the topography of each intersection differs, the impact of road grade on the traffic signal timing must be evaluated on an individual basis. However, the City of Winnipeg being located in the relatively flat prairies, road grade is by far the least significant factor of the four outlined. Therefore, for the purposes of general signal timing evaluations, all roads will be assumed to be approximately on grade.

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[12] Hugemann, W. and Nickel, M., ***Longitudinal and Lateral Accelerations in Normal Day Driving.*** ITAI Conference, Paper #960657. 1996.

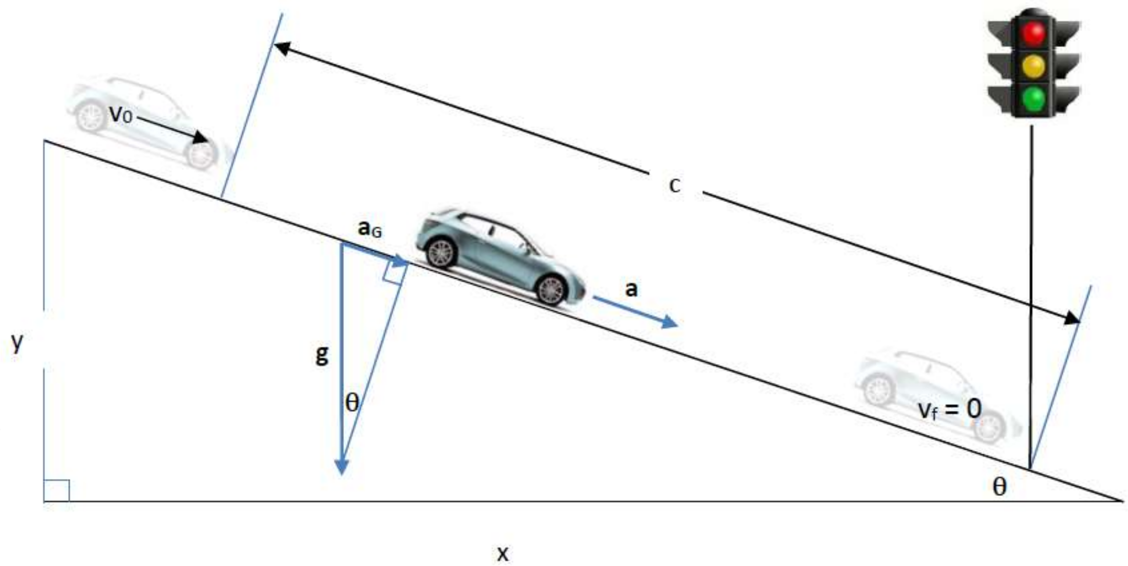

Figure 9: Graphical representation of the impact of road grade on deceleration rate.

5.3 RECOMMENDED YELLOW TRAFFIC SIGNAL DURATIONS

Based on the ITE formula outlined in Section 5.2, and the values recommended in Sections 5.2.1 through 5.2.4, the Yellow traffic signal durations were calculated. These calculated durations are presented in Table 1.

Posted Speed Limit (km/h)	Design Speed (km/h)	PRT (s)	Deceleration Rate (ft/s^2)	Approach Grade (%)	Yellow Signal Duration (s)
40	50	1.0	10	0	**3.3**
50	60	1.0	10	0	**3.8**
60	70	1.0	10	0	**4.2**
70	80	1.0	10	0	**4.7**
80	90	1.0	10	0	**5.2**

Table 1: Recommended Yellow traffic signal durations.

5.4 THE DILEMMA ZONE

The Dilemma Zone, a concept first introduced by Gazis et al in 1960, described the situation where a driver approaches an intersection and faces a traffic signal which has changed from Green to Yellow. In this case, the driver has two choices: Continue through the intersection, or apply the brakes and come to a stop. Figure 10, reproduced from Gazis' study, shows a simplified intersection diagram. The distance from the front of the vehicle to the stop bar is labelled 'x'.

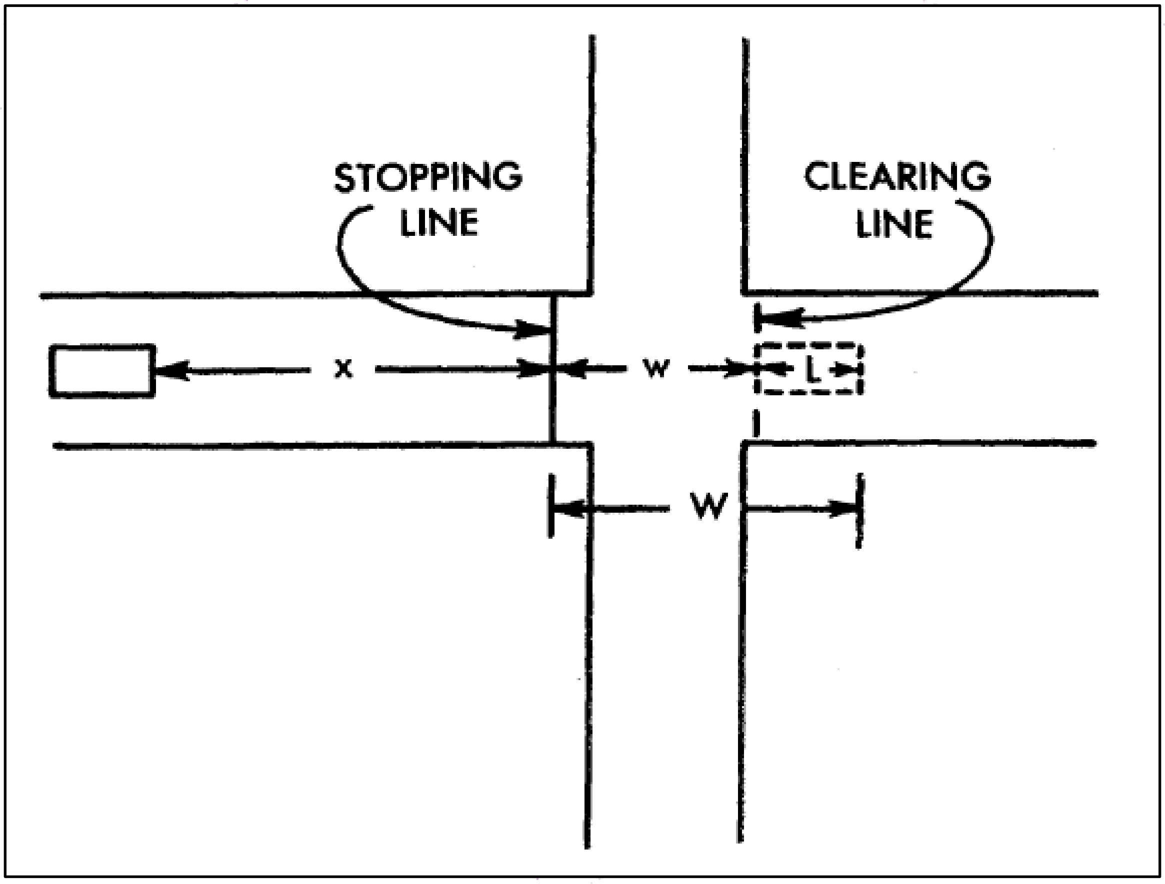

Figure 10: Intersection Diagram reproduced from Gazis.

A dilemma is created when the distance from the vehicle to the stop line, x, is not sufficient to allow for a possible, safe, and comfortable stop. In order to test whether a dilemma zone will be created, the stopping distance must be compared to the travel distance at the assumed travel speed (in the previous sections, this has been described as 'Design Speed'). In both cases, the driver must perceive the traffic signal change, then respond by either continuing through the intersection or by applying the brakes. It is the job of the traffic engineer to eliminate the existence of a Dilemma Zone. Table 2 below depicts the distances required to perform either of these actions, using the Yellow traffic signal durations from Table 1.

Posted Speed Limit (km/h)	Design Speed (km/h)	Yellow Signal Duration (s)	Travel Distance during Yellow (m)	P-R and Stopping Distance (m)	Dilemma (?)
40	50	**3.3**	45.8	45.5	No
50	60	**3.8**	63.3	62.3	No
60	70	**4.2**	81.7	81.5	No
70	80	**4.7**	104.4	103.3	No
80	90	**5.2**	130.0	127.6	No

Table 2: Dilemma Zone Evaluation.

Note that, in Table 2, the "Travel Distance during Yellow" values are always larger than the respective "P-R and Stopping Distance" values, though they are very similar. This indicates that there is no Dilemma Zone. Said another way, this indicates that, if the traffic signal changes to Yellow further away than the distance in the "Travel Distance during Yellow" column, a possible, safe, and comfortable stop is possible. Alternatively, if the traffic signal changes to Yellow closer than the distance in the "P-R and Stopping Distance" column, the driver could continue through the intersection and enter while the traffic signal was still Yellow, avoiding a violation and avoiding the safety risks associated with entering an intersection on a Red signal.

There is no question that traffic signal durations, when utilizing the correct science, create situations where typical drivers reacting reasonably can successfully and safely navigate their vehicles through signalized intersections.

5.5 IMPACT ON RED LIGHT VIOLATIONS

Data related to Red light violations was provided for the intersection at Bishop Grandin Boulevard & River Road for the years 2015 and 2016, as outlined previously in Section 3.2. It was reported that the Yellow traffic signal duration at this intersection for traffic travelling on Bishop Grandin Boulevard was 4.0 seconds. This is 1.2 seconds shorter than the ITE formula and the above-described variables recommend.

If the Red light violations were based on a Yellow traffic signal duration of 5.2 seconds rather than 4.0 seconds, 93.1 % of the violations (1546 of 1661) would not have been issued in 2015. In 2016, that percentage would have been similar, with 88.3% of the violations (1639 of 1856) not issued. Figure 11 below depicts the impacted violations.

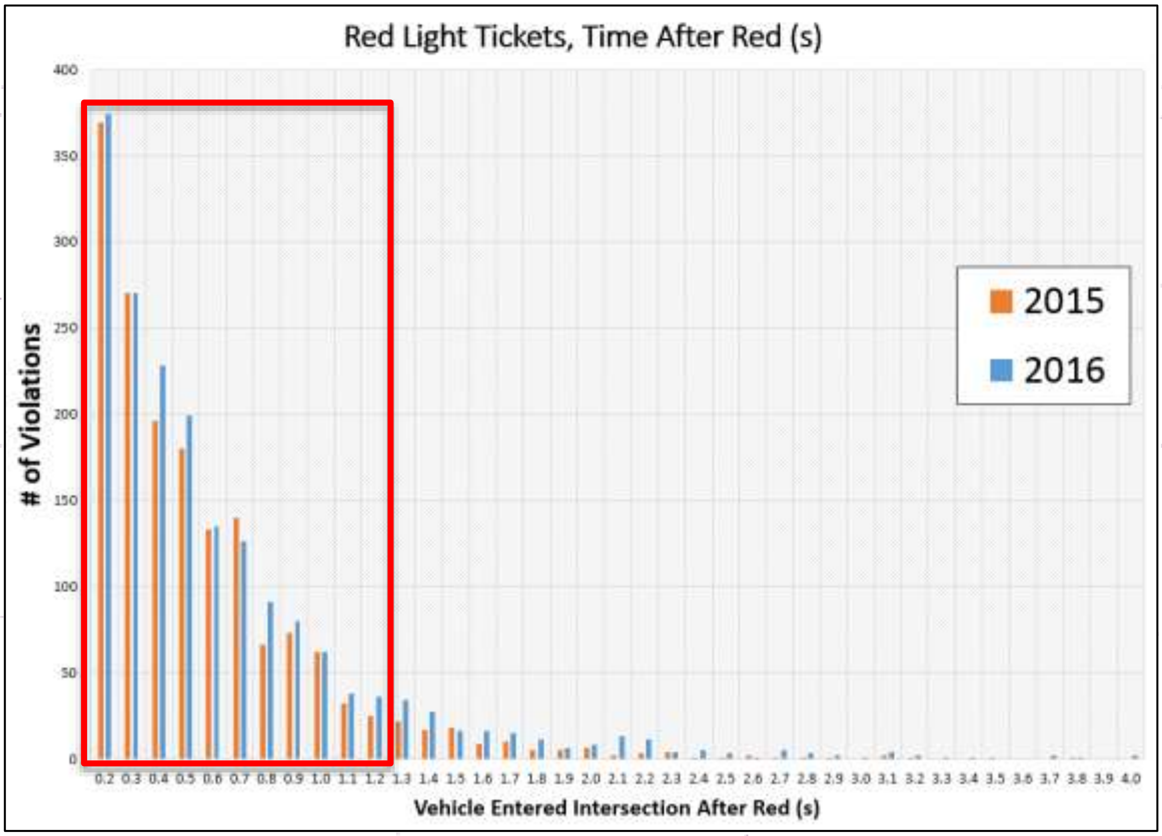

Figure 11: Impact of a 5.2 second Yellow on Red Light Violations in 2015, 2016 at Bishop Grandin Boulevard & River Road.

6.0 EVALUATION OF 4.0 SECOND YELLOW

Based on the analysis presented in Section 5.0, it is clear that a 4.0 second Yellow traffic signal duration is appropriate for some roadways and not appropriate for others. The following sections outline which roadways are which, and describe some implications of the 4.0 second Yellow traffic signal duration that show it is unreasonable in certain circumstances.

6.1 DILEMMA ZONES WITH 4.0 SECOND YELLOW TRAFFIC SIGNAL DURATIONS

As described in Section 5.4, a Dilemma Zone exists at an intersection where the Yellow traffic signal duration is such that a position on the roadway exists where neither stopping nor going through an intersection are possible, safe, and comfortable.

Unlike the analysis presented in Section 5.0, the traffic signal durations utilized in the City of Winnipeg were not based on the ITE formula. Instead, they were a constant 4.0 seconds, regardless of the speed of vehicles travelling along these roadways. A similar analysis utilizing these constant Yellow traffic signal durations was completed and the results presented in Table 3 below.

Posted Speed Limit (km/h)	Design Speed (km/h)	Yellow Signal Duration (s)	Travel Distance during Yellow (m)	P-R and Stopping Distance (m)	Dilemma (?)
40	50	**4.0**	55.6	45.5	No
50	60	**4.0**	66.7	62.3	No
60	70	**4.0**	77.8	81.5	Yes
70	80	**4.0**	88.9	103.3	Yes
80	90	**4.0**	100.0	127.6	Yes

Table 3: Dilemma Zone Evaluation, 4.0 Second Yellow Traffic Signal Duration.

By comparing the same calculations, it is clear that the constant Yellow traffic signal duration of 4.0 seconds is more appropriate for slower speeds (Posted 50 km/h speed limit and below) than for higher speeds (Posted 60 km/h speed limit and above). What becomes clear is that, for roadways with Posted Speed Limits of 60 km/h and above, the distance travelled during a stopping manoeuvre becomes larger than the travel distance during the Yellow. This means that, if a driver is travelling 70 km/h in a posted 60 km/h zone and the traffic signal changes to Yellow when the vehicle is between 81.5 and 77.8 metres from the stop bar, that driver is in the Dilemma Zone. In this case, if the driver continues travelling forward, he/she will enter the intersection after the traffic signal has changed to Red. If they instead decelerate at a rate of 10 ft/s^2, their vehicle will not come to a complete stop at the stop bar, and will enter the intersection facing a Red signal. In both cases, a violation occurs.

Because the Yellow traffic signal duration was constant, this problem was exacerbated as the speed increased. In the posted 60 km/h speed zone, the Dilemma Zone existed for a distance of only 3.7 meters (12.1 feet), a driving time of only 0.2 seconds. In the case of a posted 80 km/h speed zone (design speed of 90 km/h), the Dilemma Zone extended to 27.6 meters (90.6 feet), a driving time of 1.1 seconds. This is a long time in which to drive knowing that, if the traffic signal changes to Yellow during that time, far more substantial braking must take place in order to avoid a violation.

6.2 Design Speed vs. Posted Speed Limit

As described in Section 5.2.1, there exists a distribution of speeds at which vehicles travel along any given roadway. On a typical roadway, approximately 85% of vehicles travel the posted speed limit plus 7 mph (11.2 km/h) or slower. In Canada, the Geometric Design Guide for Canadian Roads[13] recommends that traffic engineers either use the 85th percentile vehicle speed (if a speed survey is available), or simply add 10 km/h to the posted speed limit to arrive at what is known as Design Speed. It states that "the selected

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[13] Bucik, J., ***Geometric Design Guide for Canadian Roads.*** Transportation Association of Canada. 1999, updated 2011.

design speed should be a logical one with respect to … anticipated operating speed". This Design Speed is a more appropriate speed to utilize in order to ensure a roadway is designed with public safety as a priority.

Though not stated explicitly, it is possible that the speed used in calculations related to traffic signal timing within the City of Winnipeg were based on the Posted Speed Limit, rather than the Design Speed. By utilizing the Posted Speed Limit rather than the Design Speed, the population was being held to a standard that the data shows is incorrect. This results in shorter Yellow traffic signal durations. As such, drivers facing changing traffic signals have less time to stop their vehicles, which decreases overall public safety.

Though many jurisdictions utilize the Posted Speed Limit for their Yellow traffic signal duration calculations, Design Speed should be used in order to prioritize public safety.

6.3 PERCEPTION & RESPONSE TIME (PRT)

As described in Section 5.2.2, there is a distribution of time spent perceiving and responding to a hazard such as a traffic light which has changed from Green to Yellow. Studies (many cited in this report) indicate that the median PRT of a driver responding to a changing traffic signal is 1.0 seconds.

There is no evidence which indicates what value the City of Winnipeg employs for PRT. However, by using the recommended deceleration rate (10 ft/s^2), the implied perception and response times can be calculated. The resulting PRTs are presented in Table 4. Note that, as the speeds increase, the available PRT decreases, and becomes negative, implying that a driver would be required to anticipate the traffic signal change rather than reacting to it after it changed.

Posted Speed Limit (km/h)	Design Speed (km/h)	Yellow Signal Duration (s)	Deceleration Rate (ft/s^2)	Implied PRT (s)	Percentile
40	50	**4.0**	10	1.72	99th
50	60	**4.0**	10	1.26	75th
60	70	**4.0**	10	0.81	10th
70	80	**4.0**	10	0.35	-
80	90	**4.0**	10	-0.10	-

Table 4: Implied PRT given Recommended Deceleration Rate, 4.0 Second Yellow.

As discussed in Section 5.2.2, the ITE recommendation regarding PRT is to use a value of 1.0 seconds, with the understanding that this corresponds with the median, or 50th percentile, driver. While an argument has been made that using a longer PRT would be more conservative, including more drivers' behaviours and increasing safety, the Yellow traffic signal durations recommended by the author in Table 1 utilize a 1.0 second PRT.

It is clear that, if a driver decelerates at the ITE recommended rate (the 50th percentile rate of 10 ft/s^2), the required PRT decreases to a level no human being can accomplish.

6.4 Deceleration Rates

In Section 6.3, the PRT was calculated based on an assumed deceleration rate. It is possible, however, that the City of Winnipeg utilized a constant PRT and variable deceleration rate in its calculations. As shown in Figure 10 in Section 5.2.3, drivers clearly do not decelerate at a consistent rate, rather, there is a distribution of rates at which drivers decelerate. Using the kinematics equations discussed previously, the implied deceleration rates associated with each speed was calculated given an assumption that each driver spends the ITE-recommended 1.0 second perceiving and responding to the changing traffic signal. Table 5 outlines the results of these calculations.

Posted Speed Limit (km/h)	**Design Speed (km/h)**	**Yellow Signal Duration (s)**	**PRT (s)**	**Deceleration Rate (ft/s^2)**	**Percentile (%)**
40	50	**4.0**	1.0	7.6	20th
50	60	**4.0**	1.0	9.1	45th
60	70	**4.0**	1.0	10.6	55th
70	80	**4.0**	1.0	12.2	80th
80	90	**4.0**	1.0	13.7	90th

Table 5: Deceleration Rates Implied by 4.0 Yellow Traffic Signal Duration.

What becomes immediately clear is that, by using a 4.0 second Yellow traffic signal duration, the deceleration rates required to stop increase as the speed limit increases. When these values are compared to the distribution referred to in NCHRP Report 731 it becomes clear that, for the higher speed roadways, these deceleration rates are not appropriate. In the case of the 70 km/h and 80 km/h posted speed zone, a driver must decelerate at a rate faster than 80% of the population would undertake. In addition, these deceleration rates are so high that a driver operating their vehicle on a slippery roadway (rain, snow, or ice) would not be physically capable of coming to a stop prior to entering the intersection.

Studies conclude that drivers travelling at higher speeds decelerate at a more rapid rate than slower drivers. However, the significance of this change does not justify the rapid deceleration rates required as outlined in Table 5.

Table 6, reproduced from NCHRP Report 731, depicts this difference.

Range of Vehicular Approach Speeds			Brake-Response Time (s)	Deceleration Rate (ft/s^2)
20 to 30 mph (32 to 48 km/h)	Number of Vehicles		263	263
	Mean		1.07	8.13
	Standard Deviation		0.38	2.52
	Percentiles	15	0.77	5.89
		50	1.02	7.52
		85	1.42	10.68
30 to 40 mph (48 to 64 km/h)	Number of Vehicles		761	763
	Mean		1.03	9.26
	Standard Deviation		0.39	2.43
	Percentiles	15	0.72	7.02
		50	0.95	8.78
		85	1.38	11.36
40 to 50 mph (64 to 80 km/h)	Number of Vehicles		999	1022
	Mean		0.97	10.46
	Standard Deviation		0.36	2.64
	Percentiles	15	0.67	7.91
		50	0.90	10.03
		85	1.30	13.06
50 to 60 mph (80 to 96 km/h)	Number of Vehicles		344	353
	Mean		0.94	11.90
	Standard Deviation		0.35	2.67
	Percentiles	15	0.63	9.53
		50	0.88	11.43
		85	1.25	14.50

Table 6: Deceleration Rates Relative to Speed (Metric Added for Clarity).

What this table from NCHRP Report 731 indicates is that, yes, drivers do tend to decelerate more rapidly from a higher speed. However, these rates do not approach the rates required for a stop in a 70 km/h or 80 km/h speed zone as outlined in Table 5 (12.2, 13.7 ft/s^2).

If the goal behind the Yellow traffic signal duration is public safety, then a deceleration rate of no more than 10 ft/s^2 is a requirement. Using a deceleration rate of more than 10 ft/s^2 does not represent the public interest.

6.5 RED LIGHT RUNNING AND VIOLATION RATE

Data obtained through a Freedom of Information Request was made available to the author. This data indicated that, at the intersection of Bishop Grandin Boulevard and River Road, 1661 violations were issued in 2015 and 1856 violations were issued in 2016.

More complete data was made available for the first four months of 2016. This included 11 intersections in 50 km/h speed zones, 19 intersections in 60 km/h speed zones, one intersection in a 70 km/h speed zone, as well as the intersection at Bishop Grandin Boulevard & River Road which had a speed limit of 80 km/h.

If the Yellow traffic signal durations were set appropriately, the rate of violation at any given intersection should be similar[14]. The data for the first four months of 2016 reveals that this was not the case. For the intersections in 50 km/h speed zones, an average of 58.2 violations were issued (14.6 per month, per intersection). In the 60 km/h intersections, this number increased to 84.5 violations (21.1 per month, per intersection). At the intersection at Bishop Grandin Boulevard & River Road, however, 633 violations were issued (158.3 violations per month), almost 11 times as many as in the average 50 km/h speed zones. This is easily explained by examining the Dilemma Zone phenomenon discussed in Section 5.4 and Section 6.1. In the City of Winnipeg, with 4.0 second Yellow traffic signal durations in a 50 km/h speed zone, no Dilemma Zone exists. Therefore, Red light violations occur as a result of excessive driver speed, distracted driving, negligence, or other factors. As the speed limit increases, no additional distance is allowed for the additional stopping distance required. As such, the number of violations increased. This massive discrepancy in Red light violations as a function of speed limit should be perceived as a red flag that something is wrong with the Yellow traffic signal durations in 80 km/h speed zones within the City of Winnipeg.

[14] This is assuming the traffic volume levels are such that vehicles are entering the intersection within the Yellow traffic signal phase, and that the total number of signal cycles per day is similar.

The intersection at Century Street & Silver Avenue, with a speed limit of 70 km/h, had only 67 violations (16.8 violations per month). This is interesting, as the model in the previous paragraph would suggest that the number of violations should be higher than the 60 km/h speed zones, but fewer than the 80 km/h speed zones. One possible explanation is that the speed of vehicles travelling down Century Street is reduced as a function of intersection geometry or heavy traffic. Utilizing Google Maps Traffic, the 'Typical traffic' within the northbound lanes of Century Avenue (the direction in which the traffic camera detects violations) appears to be moderate or heavy for the bulk of the day, beginning at approximately 7:45 a.m. and staying moderate or heavy until 5:45 p.m. with sparse breaks in the late morning and early afternoon. This could have the effect of reducing the speed of traffic closer to 50 km/h, resulting in red light violations more in line with a 50 km/h speed zone. Figure 12 depicts the Google Maps Typical Traffic for northbound Century Street & Silver Avenue on a Monday at 11:00 a.m.

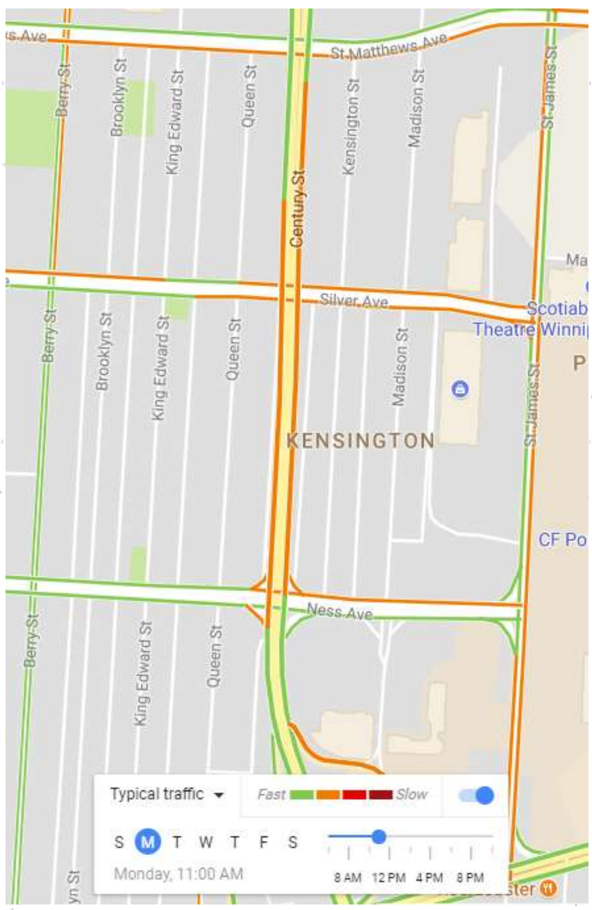

Figure 12: Typical Traffic on Northbound Century Street & Silver Avenue.

In contrast, the intersection of Bishop Grandin Boulevard & River Road did not exhibit the same heavy traffic patterns described at the intersection of Century Street & Silver Avenue. As such, traffic would be expected to travel at its full speed, likely close to 90 km/h, for most if not the entire day.

6.6 Discussion & Recommendations

The analysis presented in the above sections make it clear that the 4.0 second Yellow traffic signal duration does not comply with competent traffic engineering practices. Many of the studies referenced in this report were authored within the last 30 years, and some within the last 10 years. It is possible that the decision to create a standard 4.0 Yellow traffic signal duration was made more than 30 years ago, by a person who did not have access to these studies. In fact, NCHRP Report 731 indicates that only 6% of survey respondents used a uniform Yellow traffic signal duration for all intersections.

It is recommended that the Yellow traffic signal duration be revisited and modified using the ITE formula and the recommended values for velocity (Posted Speed Limit + 10 km/h), perception and response time (1.0 seconds or greater), and deceleration rate (10 ft/s^2 or below).

Deficient Yellow traffic signal durations create a safety risk. Drivers turning left in front of oncoming vehicles, as well as perpendicular traffic travelling straight through the intersection, are at the highest risk. Yellow traffic signals that are too short put these drivers and their passengers at risk of a broadside collision, the most dangerous vehicle collision orientation. Requiring drivers to decelerate rapidly (i.e. slam on the brakes) in response to a changing traffic signal also increases the risk of rear end collisions. As noted, typical drivers do not decelerate at the rates required by these deficient Yellow traffic signal durations. This rapid deceleration, if not carried out by trailing drivers, result in rear-end collisions.

An administrative report titled “Traffic Study – Bishop Grandin Boulevard” endeavoured to evaluate the relative safety of 1921 regional intersections (500 of which were signalized). Of those, five of the top 20 intersections with the highest Excess Collisions were on Bishop Grandin Boulevard. Several of the other intersections in the Top 20 had speed limits of 80 km/h. The intersection at Bishop Grandin Boulevard & River Road ranked 39 out of 1921 intersections.

While traffic collision rates are a function of many factors, the deficient Yellow traffic signal timing was a contributing factor. Continuing to employ a 4.0 second Yellow traffic signal duration will contribute to traffic fatalities in the future, and may have contributed to traffic fatalities in the past. The report recommends "a safety audit to be completed" on these roadways as part of "short term and long term potential road safety mitigation measures." The author agrees, and recommends that the Yellow traffic signal duration be a part of this audit.

7.0 VIOLATION OF MR. AISAICAN-CHASE

The details of Mr. Aisaican-Chase's violation were provided. The following sections outline the circumstances faced by Mr. Aisaican-Chase and an evaluation of his response.

7.1 POSITION OF AISAICAN-CHASE VOLKSWAGEN AT SIGNAL CHANGE

According to Mr. Aisaican-Chase's violation notice, his Volkswagen entered the intersection 0.29 seconds after the traffic signal changed to Red. As discussed previously, the Yellow traffic signal duration was 4.0 seconds. Therefore, the traffic signal changed from Green to Yellow 4.29 seconds prior to the Aisaican-Chase Volkswagen entering the intersection.

Mr. Aisaican-Chase stated that he was did not accelerate or brake during his travel toward the intersection. According to Mr. Aisaican-Chase, his Volkswagen was travelling 80 km/h. Therefore, the front of the Aisaican-Chase Volkswagen was 95.3 metres (312.7 feet) from the stop bar when the traffic signal changed from Green to Yellow.

7.2 EXPECTED RESPONSE AND DRIVER ACTION

As discussed in Section 5.2.2, drivers require a period of time to perceive a traffic signal change and respond to that change. Studies show that typical, attentive drivers respond to a hazard such as a changing traffic signal in approximately 1.0 seconds on average. This average is for the entire population, including drivers both young and old. Assuming that Mr. Aisaican-Chase required only 1.0 seconds to respond while travelling 80 km/h, his Volkswagen travelled 22.2 metres (72.9 feet) during his response interval.

In order to avoid a violation, Mr. Aisaican-Chase was required to stop his Volkswagen prior to entering the intersection. After a 1.0 second perception and response interval, 73.1 metres (239.8 feet) remained in which to stop. This indicates that Mr. Aisaican-

Chase would have been required to decelerate at a rate of 11.1 ft/s^2 (3.38 m/s^2, 0.34 g). From the distribution presented in Figure 10 in Section 5.2.3, this deceleration rate represents the 70th percentile deceleration rate at which typical drivers slow for a planned stop. Said another way, only 30% of drivers would decelerate at the elevated rate required to stop prior to entering the intersection.

At the time of the violation, Mr. Aisaican-Chase was 71 years of age. As previously outlined, older members of the population require more time, on average, to respond to hazards. From Olson & Dewar, drivers 56 years and older applied the brakes 0.3 seconds later than drivers 18 – 30 on average. Based on all of the research reviewed, a driver in Mr. Aisaican-Chase's position may have spent up to 1.5 seconds perceiving and responding to the changing traffic signal. Had his PRT been 1.5 seconds, his Volkswagen would have travelled 33.3 metres (109.3 feet) during this response interval.

In this case, in order to avoid a violation, Mr. Aisaican-Chase would have been required to stop in the remaining 62.0 metres (203.4 feet). This would have required a deceleration rate of 13.1 ft/s^2 (3.98 m/s^2, 0.41 g). This deceleration rate represents the 85th percentile deceleration rate, a rate at which only 15% of drivers employ.

Had Mr. Aisaican-Chase decelerated at a rate of 10 ft/s^2, he would have spent 81.0 metres (256.6 feet) decelerating. This left only 14.3 metres (47.1 feet) with which to perceive and respond to the changing traffic signal. At a speed of 80 km/h, that distance would have been travelled in only 0.65 seconds. As described previously, very few if any drivers could respond to the changing traffic signal in this time. Most drivers respond in times nearly twice this requirement.

This situation in which Mr. Aisaican-Chase found himself is an example of the Dilemma Zone discussed in Section 5.4. Clearly, at a distance of 95.3 metres from the intersection, Mr. Aisaican-Chase could not continue through without committing a violation. However, Mr. Aisaican-Chase was also not able to stop unless he decelerated rather severely. Had he decelerated at the published median rate of 10 ft/s^2 (3.05 m/s^2, 0.31 g), his Volkswagen would have come to a complete stop 7.9 – 19.0 metres (25.8 – 62.3 feet) beyond the stop bar, well into the intersection. In this scenario, Mr. Aisaican-Chase's arrival into the intersection would have been delayed by braking. He would have arrived in the intersection 8.3 – 8.8 seconds after the traffic signal turned Yellow. At this time, the traffic perpendicular to Mr. Aisaican-Chase would have had a Green traffic signal, and as such, would have been in danger of colliding with his Volkswagen.

7.3 IMPACT OF 4.0 SECOND YELLOW TRAFFIC SIGNAL DURATION

Because the Yellow traffic signal facing Mr. Aisaican-Chase had a duration of only 4.0 seconds, his vehicle was too far away to travel through the intersection without committing an offense, while at the same time too close to stop safely and comfortably. In this case, had Mr. Aisaican-Chase decided to stop, he would have been required to decelerate at a rate faster than between 15 and 30% of all other drivers. Requiring a driver to decelerate at this rapid rate may have created an unnecessary hazard to both Mr. Aisaican-Chase, and to the drivers in his immediate vicinity. Had there been a vehicle immediately behind his, and Mr. Aisaican-Chase began to rapidly decelerate, the risk of a rear-end collision would rapidly increase. Had the Aisaican-Chase Volkswagen been rear-ended, it almost certainly would have ended up within the intersection and in a vulnerable position as left-turning traffic proceeded and perpendicular traffic entered the intersection.

Alternatively, for Mr. Aisaican-Chase to avoid by decelerating as a typical driver, his perception and response time would have been approximately half of what would be expected of a typical driver in his position. It is completely unreasonable to expect a driver in his position to respond in this short period of time.

Therefore, Mr. Aisaican-Chase's decision to proceed through the intersection at Bishop Grandin Boulevard & River Road was reasonable and represented the safest option. Had the Yellow traffic signal duration been 5.2 seconds as the ITE formula recommends, the Aisaican-Chase Volkswagen would have entered the intersection facing a Yellow traffic signal, and no violation would have been issued. The deficient Yellow traffic signal duration is the primary reason for the traffic violation.

8.0 CONCLUSIONS

1. The ITE formula for Yellow traffic signal duration is based on the kinematic equations.
2. The speed of traffic on any given roadway is a distribution, not a discreet value.
3. Traffic on any particular roadway travels faster than the Posted Speed Limit. As such, the Design Speed (Posted Speed Limit + 10 km/h) is a more appropriate speed to use when calculating Yellow traffic signal durations.
4. The perception and response time of drivers responding to changing traffic signals is a distribution, not a discreet value.
5. The average driver requires at least 1.0 seconds to perceive and respond to a traffic signal which has changed from Green to Yellow. As such, at least 1.0 seconds should be used when calculating Yellow traffic signal durations.
6. Deceleration rates of vehicles as they approach a planned stop are a distribution, not a discreet value.
7. The average driver decelerates at a rate of 10 ft/s^2 or less when approaching a planned stop, such as a Yellow traffic signal.
8. The approach grade for each intersection must be evaluated on an individual basis.
9. The recommended Yellow traffic signal duration for a roadway with a Posted Speed Limit of 80 km/h is 5.2 seconds.
10. A Dilemma Zone exists when the distance required to stop (including the perception and response) exceeds the distance travelled during the Yellow signal.
11. For the recommended Yellow traffic signal durations, no Dilemma Zone exists.
12. If the Yellow traffic signal duration was increased to 5.2 seconds from 4.0 seconds, 88 - 93% of the Red light violations would not have been issued at Bishop Grandin Boulevard & River Road.
13. Dilemma Zones exist for Yellow traffic signal durations of 4.0 seconds on roadways with Posted Speed Limits of 60 km/h or greater.

14. If a constant deceleration rate is required to stop for each different speed zone within the City of Winnipeg, the PRT required to stop decreases as the Posted Speed Limit increases. In the case of an 80 km/h speed zone, the PRT required becomes negative, meaning that the driver must anticipate the changing traffic signal and respond before it changes.

15. If different deceleration rates are required to stop for each different speed zone within the City of Winnipeg, they exceed the recommended 10 ft/s^2, and often exceed what a typical driver could accomplish given the variable weather conditions in Winnipeg.

16. Drivers decelerate at a higher rate when travelling at a higher speed. However, this effect does not justify the high decelerations required, in some cases as high as 13.7 ft/s^2.

17. The Yellow traffic signal duration should be revisited and modified to use the ITE formula in order to prevent severe vehicular collisions, specifically on roadways with Posted Speed Limits above 60 km/h.

18. Mr. Aisaican-Chase found himself within the Dilemma Zone, and could neither continue through the intersection nor decelerate at a reasonable rate without committing a violation.

19. In order to stop by decelerating at a reasonable rate, Mr. Aisaican-Chase would have had to perceive and respond to the changing traffic signal in 0.65 seconds, a duration approximately half that which would be expected of a typical, attentive driver.

20. The decision by Mr. Aisaican-Chase to proceed through the intersection at a constant speed of 80 km/h was reasonable and represented the safest option.

21. The deficient Yellow traffic signal duration on Bishop Grandin Boulevard & River Road was the largest contributor to Mr. Aisaican-Chase's violation.

APPENDIX A

LIST OF PROVIDED DOCUMENTS

LIST OF PROVIDED DOCUMENTS

- Letter from Mr. Robert Zaparniuk, dated July 13, 2017
- Photograph of Aisaican-Chase Volkswagen in the intersection while traffic light was Red, dated October 26, 2015
- Offense Notice, dated October 26, 2015
- Schedule D related to violation, dated July 27, 2016
- Vehicle registration information for Aisaican-Chase Volkswagen
- Transcript of Evidence at Trial, Mr. Jim Aisaican-Chase, dated April 26, 2017
- Winnipeg Public Works Department Report, “Traffic Study – Bishop Grandin Boulevard”, dated November 15, 2016
- Time into Red data for 2015, 2016 on Bishop Grandin Boulevard & River Road
- Violation counts for 32 intersections, first four months of 2016 (by intersection)

APPENDIX B

CURRICULUM VITAE
DARRYL W. SCHNARR, P.ENG.

17R06031

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Education

UNIVERSITY OF WATERLOO, WATERLOO, ON

Faculty of Engineering

Bachelor of Applied Science, Mechanical Engineering – Co-operative Program (With Distinction)

Specialized Professional Competencies

Inspected damaged vehicles, undamaged vehicles, and collision scenes related to a reported collision.

Reconstructed motor vehicle collisions involving automobiles, heavy trucks, trains, motorcycles, all-terrain vehicles, bicycles, skateboards, and pedestrians. Employed a combination of engineering software packages and hand calculations to solve complex collision dynamics.

Calculated collision forces and directions for use in biomechanical injury evaluations.

Assessed mechanical fitness of automobiles. Suspected issues included brake failures, accelerator pedal failures, tire tread inadequacy, fuel system failures, vacuum system failures, and suspension component failures.

Assessed mechanical fitness of motorcycles. Suspected issues included air box failures, fuel system failures, braking system failures, position of handlebar mounted controls, suspension failures, and tire failures.

Vehicle Event Data Recorder (Black Box) removal, downloading, and analysis.

Restraint and safety system usage and failure analysis, including seatbelts, air bag systems, and helmets.

Investigation of suspicious / fraudulent vehicle collisions, where the occurrence of a collision between two or more vehicles is in question.

Mechanical systems evaluation and failure analysis, including elevators and scaffolding failures.

Firearm failure, accidental discharge, and holster interaction analysis.

Forensic Engineering Experience

ROAR ENGINEERING — **Jun 2016 – PRESENT**
Forensic Engineer, Accident Reconstruction Manager

GIFFIN KOERTH INC. — **Nov 2009 – Dec 2013**
Forensic Engineer, Accident Reconstruction

FORENSIC DYNAMICS INC. — **May 2008 – May 2009**
Forensic Engineer, Accident Reconstruction

Industrial / Manufacturing Experience

HAMMOND MANUFACTURING — **Nov 2015 – Jun 2016**
Senior Methods Engineer

OWENS CORNING GUELPH GLASS PLANT — **Jan 2014 – Nov 2015**
Chopped Strand Mat Process Engineer

TRACTION TECHNOLOGIES — **May 2006 – May 2008**
Project Engineer

TOYOTA MOTOR MANUFACTURING CANADA — **Sep 2004 – Aug 2005**
Manufacturing Engineering Student

CAMI AUTOMOTIVE — **Sep 2002 – Dec 2002**
Maintenance Support Student

Additional Courses and Seminars

COURSES COMPLETED

Confined Space Entry Certified, Acute Environmental and Safety Services, 2014

Crash Data Retrieval (CDR) Analyst Course, Collision Safety Institute, 2013

Society of Automotive Engineers (SAE) International Congress, 2012

Society of Automotive Engineers (SAE) International Congress, 2011

Canadian Firearms Safety Course (CFSC), 2001

Experienced Rider Motorcycle Training Course, Conestoga College, 1999

Motorcycle Driver Training Course, Conestoga College, 1998

Professional Memberships

Professional Engineers of Ontario (PEO)

Society of Automotive Engineers (SAE)

Canadian Association of Technical Accident Investigators and Reconstructionists (CATAIR)

Institute of Transportation Engineers Inc. (ITE)

Court Experience

Qualified as an expert witness in the Ontario Court of Justice.

Qualified as an expert witness in the Ontario Superior Court of Justice.