Presentation of the stakeholders

Ministère des transports du Québec

The mission of the Ministère des transports du Québec (MTQ) “to ensure the mobility of people and goods throughout Quebec with an efficient and safe transportation system that contributes to the sustainable development of Quebec”.

The MTQ is responsible for 29,000 kilometers of highway and over 4,900 major structures.

CIMA+

CIMA+ is a multidisciplinary firm with offices in several regions of Quebec, including three offices in the Montréal metropolitan area.

The CIMA+ Traffic Engineering Group includes several highly skilled teams specialized in the many aspects of transportation planning, including transportation plans, origin-destination studies and traffic modeling. In addition, the Group has led numerous road construction projects and conducted opportunity studies as a part of comprehensive transportation projects.

Moreover, the CIMA+ Transportation Engineering Division routinely conducts highly complex traffic flow and roadway geometry studies, in addition to providing design, implementation and construction services for all types of roadway structures.

As part of this project, the CIMA+ Transportation Engineering Division has assembled a team of transportation safety specialists to assess an innovative method to determine a highway structure’s optimal safety level. To that end, the team is conducting several technical studies aimed at increasing the “user-friendliness” of high-use roadways and improving safety conditions in locations designated as problem areas by municipal authorities and other government agencies.

Innovative aspect of the project

In Quebec, road safety assessments are generally conducted using traditional indicators, such as accident rates, crash severity indices, etc. However, as part of the Turcot Interchange Reconstruction Project, an innovative method based on the empirical Bayesian approach has been retained. This method allows for the adaptation of standard American predictive models to take local accident characteristics into account, thereby producing a model that better reflects the actual road safety conditions of Montréal’s highway network.

Overall Applicability of the Method

The development of a utility program enables designers to modify design parameters and to assess the safety gains and losses flowing from these modifications. This tool will also be of assistance to the specialists conducting the road safety audit aimed at identifying the safety risks associated with the proposed infrastructure. The final preliminary design of the interchange concept will be produced within the framework of a public-private partnership. This tool will allow planners to estimate gains and losses for the entire duration of the mandate, once the concept is finalized.

This study will serve to increase awareness of the Bayesian Empirical Method among Quebec's transportation and road safety specialists.

Project Presentation

1. Project context

Located in the southwest quadrant of the Island of Montréal, the Turcot Interchange is a major component of the City's highway system. A detailed assessment of the overall condition of this structure conducted by MTQ authorities in 2004 concluded that the full reconstruction of this major crossroads is necessary. Subsequently, a consortium that includes CIMA+ was given the mandate to provide a detailed functional assessment of the interchange and the highways flowing through it. Several scenarios were developed, and the preferred solution involves lowering the profile of the existing elevated roadways, the disenclavement of the urban area underneath and the reconfiguration of the La Vérendrye and Angrignon interchanges.

In order to build a safer structure, the MTQ wishes to develop a quantitative assessment method reflecting the specific characteristics of the Turcot Interchange. This method will demonstrate the gains in road safety achieved by the proposed scenario, in comparison with the existing configuration. As part of the overall project, the CIMA+ team was given the mandate to develop a road safety assessment methodology. Of all approaches considered, the Bayesian Empirical Method (EB) was selected.

2. Methodology

In Quebec, the calculation of accident rates is the most commonly used quantitative method for road safety assessments. However, in assessing the road safety factor for the proposed design scenario for the new Turcot Interchange, this method presents certain limitations given the size and complexity of the structure in question.

In order to provide the optimal degree of safety to all users of the reconfigured Turcot Interchange, it is essential to identify and improve the weakest components of this highly complex structure. In an effort to achieve the highest degree of precision in the road safety assessment of the proposed design scenario, the Bayesian Empirical Method was selected. This method will allow for the comparative analysis of the existing Turcot Interchange configuration and the proposed design scenario.

2.1 Description of the Bayesian Empirical Assessment Method

The Bayesian Empirical Method (EB) is based on the combination of two variables to obtain an "estimated number of accidents". These two variables are described below:

1. Number of accidents observed on site (classic estimator);
2. Average number of accidents for similar locations (reference population).

It should be noted that the average accident rates for the reference population are established using accident prediction models known as the "safety performance function" (FPS).

Formulae

With the EB Method, the estimated number of accidents (f_{EB}) is calculated as shown below. It should be noted that this is a simplified version of the method used to establish a link between the two sources of information combined. The figure below shows the formula used in this study.

$$f_{EB} = w * f_P + (1-w) * f$$

Where

f_{EB} = Estimated number of accidents

w = Weighting factor (weight)

f_P = Predicted number of accidents, based on FPS

f = Number of accidents observed on site

The weighting factor « w » is calculated as follows:

$$w = \frac{K}{K + (n*FPS)}$$

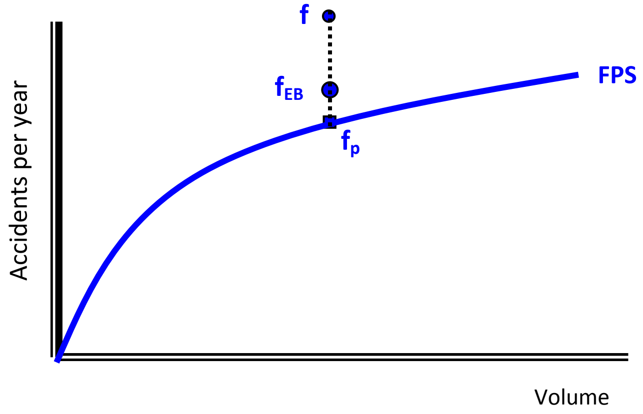
Where

k = Overdispersion parameter (defined constant)

n = Number of years

Figure 1 provides a graphic representation of the Bayesian Empirical Method.

FIGURE 1: LINK BETWEEN THE NUMBER OF ACCIDENTS OBSERVED ON SITE AND THE ESTIMATED NUMBER OF ACCIDENTS, USING THE EB METHOD



In this figure, the “f” value represents the number of accidents observed at a given location. The Safety performance function, represented by the curve, illustrates the predicted number of accidents for a reference population (fp) under comparable traffic volume conditions. The EB Method combines the “f” and “fp” values to obtain the estimated number of accidents, or “f_{EB}”.

It should be noted that the long-term safety index of a given structure or facility is determined by the “f_{EB}” value. Indeed, the PIARC Road Safety Manual specifies that practitioners and decision-makers should base their road safety related activities and decisions on “estimated number of accidents” projections as this is the most effective predictor of accident frequency in the long term[1].

Calculation of road safety gains or losses by comparing the existing geometry and the proposed scenario (Revised Concept 1.1)

Estimated road safety gains or losses are obtained by comparing the estimated number of accidents factors for the existing configuration and Revised Concept 1.1. The reference year for this comparison is 2016, which corresponds to the estimated project completion date.

Aspects to be assessed

The Safety performance function (FPS) is obtained by using statistical models that take into account exposure along with other geometric features, including the nature of the setting, number of lanes, interchange type, etc. However, the FPS does not consider all of the geometric characteristics having a significant impact on the Turcot Interchange’s level of safety, including the following:

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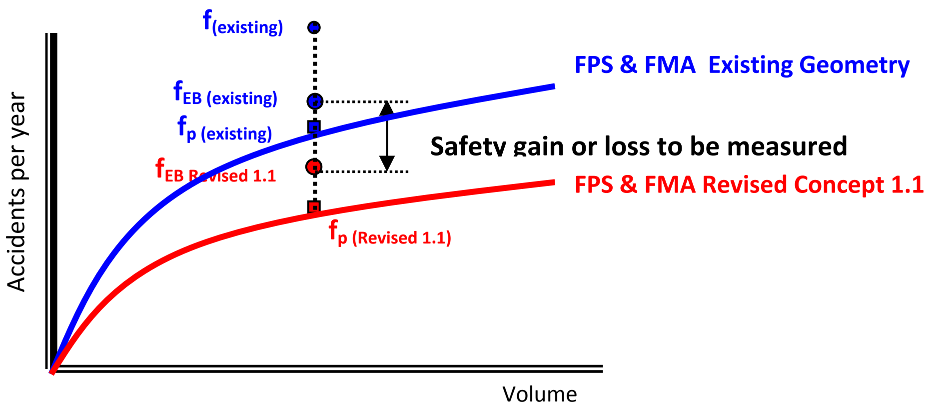
[1]. World Road Association (PIARC), *Road Safety Manual*, 2003, p. 120.

- Width of the inside and outside shoulders and width of the traffic lanes;
- Number and length of the areas for convergence, divergence and lane-changing;
- Horizontal and vertical profiles;
- Superelevation;
- Taper lengths.

To rectify this situation, it is necessary to add Accident Modifying Factors (FMA) to the FPS. These FMA values are developed through “before and after” studies that determine the ratio of accident frequency measured before and after any specific intervention. Consequently, all FMA values are multiplied by a FPS to obtain a representative model of before and after conditions.

This approach is illustrated in Figure 2.

Figure 2 : Relation between the estimated number of accidents for the existing geometry compared to Revised Concept 1.1 using the EB Method



On the figure above, the estimated number of accidents (f_{EB}) for the existing geometry is shown in blue, while the estimated number of accidents (f_{EB}) for Revised Concept 1.1 is shown in red. The difference in the estimated number of accidents between the existing configuration and Revised Concept 1.1 corresponds to the measured road safety gain or loss, if any.

Selected Safety Performance Functions

The analysis of Safety Performance Functions (FPS) based on the studies outlined previously indicate that the FPS developed by the Federal Highway Administration (FHWA) in 2007 appear to be the best suited to the Turcot Complex. Indeed, this study encompasses all possible types of structures found on a highway network. More specifically, these FPS take into account highway sections, on- and off-ramps, interchange ramps and acceleration and deceleration lanes.

3. Presentation of results

A utility program was developed to enable Bayesian Empirical Method (EB) calculations using Excel software. This tool estimates changes in the number of accidents and gains and/or losses based on proposed changes in the design of the interchange complex, (lane width, shoulder width, etc.), along with changes in traffic volumes.

The utility program is capable of estimating road safety gains and losses between 1999 and 2016.

Analysis of results

Estimated road safety levels were developed for all sections of the existing roadway network and Revised Concept 1.1.

Pour each traffic maneuver, the key safety indicators used to determine safety impacts are the safety index and the estimated number of accidents per year. Both indicators are used to illustrate the results in terms of total accidents and accidents involving bodily harm.

Safety index results lower than a factor of 1 indicate a gain in road safety, while results above a factor of 1 indicate a loss in road safety. During data interpretation, it was noted that several geometric characteristics have a considerable effect on the results. One of these key characteristics in the length of maneuver, as results indicate the longer the section, the longer the exposure to risk. For certain maneuvers whose length was increased, results indicated a loss in road safety despites the improvement of other geometric characteristics, such as shoulder widening. A detailed interpretation of results was conducted for the maneuvers in question.

4. Conclusions

Overall, Revised Concept 1.1 offers a gain in safety level, as the safety index is lower than 1. This gain is mainly attributed to the addition of inside and outside shoulders on the main thoroughfare, offering drivers a recovery zone. Specifically in regards to accidents involving bodily harm, it was noted that the majority of maneuvers show gains in safety level when compared to existing conditions.

In addition, certain maneuvers now feature a longer maneuvering space. However, this has the effect of increasing risk exposure, thereby increasing the estimated number of accidents. Nevertheless, this increase in usable roadway provides other gains in road safety that cannot be quantified with this method. For example, longer maneuvering distances mean longer lane-changing distances and longer acceleration and deceleration lanes, in addition to eliminating the need for left side on ramps. In analyzing these maneuvers, the increase in risk exposure des not tell the whole story, as it can be offset by the safety gains achieved through improved geometrics.