EXPLORING ROAD SAFETY ANALYSIS AND STAKEHOLDER ENGAGEMENT FOR SMALL AND MEDIUM SIZED COMMUNITIES

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ABSTRACT

Identifying thematic issues and Accident Prone Locations (APLs) on rural local road network is challenging because of the length and scope of the network and the spatial and temporal variability of crashes. The objective of this paper is to explore the complementarity between road safety stakeholders' subjective point of view and the more objective identification of APLs through an Empirical Bayes (EB) method in a rural, less-dense area of Quebec, Canada. The first step of the method consists in EB analyses with a spatial database containing the accident data, the road network and several environmental attributes of the road sites. The second step is to recruit, interview and summarize systemic safety issues based on the perceptions of various stakeholders, both spatially and thematically. An application of this comparative method in a local and predominantly rural county of 23 municipalities in Quebec shed light on the usefulness of combining qualitative and quantitative data in the identification of systemic issues and possible APLs. The knowledge of the stakeholders gives an insight on the most important road safety issues, while the quantitative analyses tend to both confirm and nuance the APLs to be further investigated.

Keywords: Road Safety, Accident Prone Locations, Systemic issues, Stakeholder engagement, Empirical Bayes Method, Small and Medium-sized communities

INTRODUCTION

In the Province of Quebec (Canada), more than 75 % of the roads are under the jurisdiction of municipalities. Overall, half of vehicle crashes with personal injuries and 42 % of fatal and serious injuries happen on the municipal network (*1*). Most crashes are at least in part caused by human factor, but road environment improvements can play a critical role in reducing the number and severity of them. To achieve these improvements, the Quebec ministry of Transportation (MTQ) encourages municipalities to implement local road safety programs, based on road safety analyses, helping to prioritize interventions in terms of engineering, education and enforcement.

However, the municipal road network is hard to describe outside of its administrative dimension. It consists of streets that may have very different functions: roads at the junction of freeways (collectors), residential and commercial streets in regional towns, or long rural roads through extended agricultural and woodland. In bigger cities, the municipal road network is mostly used for shorter trips and local traffic. In rural areas, transit traffic adds to and conflicts with local traffic and pedestrian activities, often going through the main street. This leads to a scattered spatial distribution of crashes throughout the network, a pattern harder to study under usual safety analysis methodology aiming to identify accident-prone locations (APLs) (*2-4*).

Determining accident prone locations (APL): challenges for rural areas

The identification of APLs is one of the main goals of road safety analysis, in order to prioritize the investment made in certain sections of the road network, especially under municipal budget restriction (*1, 5*). More specifically, it is to identify objectively road segments and intersections on the road network, which may require further investigations, through cost-benefit analysis of safety measures for example. Also called hot spots or black spots, the APLs are characterized by a higher number of expected crashes that is also more severe than at other similar sites (*6-9*). The general consensus to identify APLs is to use the Empirical Bayes method (EB) (*6, 10*). Nevertheless, these road safety studies demand a high budget if a Bayesian approach is implemented following the best practices, in particular since traffic measurements are required to effectively estimate the expected number of crashes by the EB method. Moreover, in small and medium sized communities, the identification of APLs may be hindered due to the scattered and low number of crashes on rural roads.

In such conditions, how can road safety analysis be done effectively, in a way that helps municipalities to implement local road safety programs and countermeasures? Many local and regional road safety stakeholders have knowledge of the municipal context, in terms of resources, finance and expertise of the road network, in particular through citizens' complaints and knowledge of accident history. This represents an opportunity to add relevant information to an APL analysis. However, is it relevant to incorporate subjective information related to risk perception to the analysis of accident data, and how can such information be integrated?

The usefulness of local stakeholders in a road safety analysis

In order to diagnose a complex decision making problem such as hotspot identification, experts must recognize both the limitations of rational models based only on objective data and the difficulty to analyse a situation independent of the observers (*11, 12*). Based on the concept of advocacy planning (*13*), transport planners are now more and more aware of the necessity to create opportunities during a process of road safety analysis for stakeholders to share their concerns and experiences, defend their interests and encourage policy choices that will sustain their actions. Incorporating personal preferences and risk perception in a decision process also presents limitations: the judgement relies on biases and heuristics that may reinforce or attenuate the severity of a problem or the situation and influence the process of selecting effective responses (*14, 15*).

However, engaging the community in the process, in order to identify, discuss, understand and promote feasible transport solutions is recognized as an essential tool for many transportation authorities to support the decision process (*16-18*).

First, engaging stakeholders in a road safety analysis gives a voice to several municipal-level actors: civil servants, elected representatives, transportation engineers, police services, civil organizations promoting various modes of transportation and access to activities, all of them having local experience, field knowledge, or at least opinions on diverse issues about local road safety (*17*). They can then help to identify issues that would not be raised by statistics or other quantitative analysis, especially in rural areas, as argued before. Secondly, it helps to take into account past solutions and recurring problems, to look into details of salient issues: perceived explanatory factors by these actors may be different from what is evidenced by the data (*16*). Thirdly, engaging stakeholders fosters communication and dialog during the process and after, within the community and at large, but also between the stakeholders themselves that can help each other to solve problems. Such an involvement has the potential to enhance the local government awareness and empower the community to play an active role in the identification and resolution of road safety problems.

The objective of this paper is to explore the complementarity between road safety stakeholders' point of view and the identification of systemic issues and APLs in a rural, less-dense area of Quebec, Canada. A four-step method is proposed to include stakeholders' point of view in this road safety analysis: 1) To integrate all relevant data, including crash reports, road geometry, traffic flows and environmental variables within a spatial database; 2) To initiate a consultative process with local road safety stakeholders and to extract road safety concerns from stakeholders' discourse; 3) To determine APLs using the EB method; 4) To compare results from the EB analysis with the information gathered from stakeholders related to the road safety issues (i.e. which are the "factors" highlighted by each source?) and to the spatial localization of problematic sites (i.e. where are the "hot spots" identified by each source?).

METHODOLOGY

Study Area

The case study is part of a pilot road safety diagnosis, funded by the Quebec ministry of Transportation (MTQ) and conducted in a medium-sized community between April 2012 and March 2014. Located halfway between Montreal and Quebec City, the Arthabaska Regional County Municipality (RCM) has 23 municipalities and a population of around 70,000 for an area of 1,890 km2 (*19*). Victoriaville is the main town with a little more than 40,000 inhabitants, but is also the main destination for work and shopping. Two other towns regroup another 7,000 inhabitants (Warwick and Kingsey Falls), while the rest of the population is disseminated over the rest of the RCM in villages and remote rural areas. Landscape and elevation also divided the rural territory in two parts: highlands to the east (hilly and woody) and lowlands to the south and west, surrounding Victoriaville (flat, pasture). This region is doing quite well in terms of population (increase of 4.5 % between 2006 and 2011, mostly in Victoriaville) and employment (unemployment rate at only 5.6 %), which puts pressure on its road network as urban cores and surrounding villages get bigger.

Step 1: To implement a spatial database for a road safety diagnosis

A spatial database is at the core of all the analyses and is mainly based on two different geographical scales: the road segments and the road intersections, illustrated by surfaces (polygons) around intersections of three or more road segments. All other geographical information is related to these two layers. Table 1 presents that information, as well as their sources and short description. All the data are present at the road segment and at the intersection level. Details about every step needed to have the final database are available upon request to the corresponding author. For the purpose of the present paper, we will only use three layers: the crashes (on road segments and at intersections) and their attributes; the road environment layer (including all the attributes related to specific characteristics of intersections and road segments) and the stakeholders' map of road safety issues on the RCM territory. The road network was also used in order to build a raster dataset for our comparative analysis.

TABLE 1 Complete dataset associated with the Arthabaska pilot road safety diagnosis

Data	Source	Most used attributes
Hierarchical road network	MTQ	- Intersections: Municipal or Municipal/MTQ responsibility - Road segments: number of lanes, paved or not, functional classification of the road (local, arterial, collector, highways)
Accident data (2007-2011)	MTQ	- Accident characteristics (number of victims, injury severity, time, factors/causes, impact type) - Vehicle or road user characteristics (type of vehicle, including pedestrians and cyclists) - Individual driver or pedestrian characteristics (age, gender, postal code of the home location)
Traffic Flow	*Field data collection*	- Traffic flow of intersections and road segments for a limited sample of road categorised according to the functional classification
Road environment	*Field data collection*	- Intersections: type of intersection (T, X), type of signal control, presence of signs and markings - Road segments: exclusive right turning lane, permitted parking on the street, presence of exits/entrances to residential and commercial areas, presence of markings
Safety issues	Stakeholder interviews and workshops	- Thematic issues - Problematic segments and intersections drawn by the stakeholders on maps (categorized according to the thematic issues)
Land Use, census data and other traffic network	RCM and Statistics Canada	- Land use (urban, industrial, agricultural, forest use) - Urban perimeters of each of the villages - Population density - Presence of cycling facilities, snowmobile and quad trails

Step 2: To identify APLs with the Empirical Bayes method

The second part of the analysis was the opportunity to apply the EB method, which estimates for a site *i* the expected number of crashes (θ_i) based on the observed number of crashes (y_i) and the safety performance function based on the characteristics of the sites in the region (including variables prone to increase or decrease the expected number of crashes). The EB estimate is defined as follow:

$$EB_\theta = E(\theta_i|y_i) = w_i\mu_i + (1 - w_i)y_i \quad (1)$$

The result of the EB approach is determined by how much weight (w_i) is given to crashes expected on similar entities and by the safety performance function, SPF (μ_i). The SPF estimates the number of crashes per site using a negative binomial distribution from site characteristics such as some geometrical attributes and the Average Annual Daily Traffic (AADT) of each site. However, if the EB method is applied to a large (rural) area, it is highly probable that AADTs for each site are unavailable or the allocated budget does not permit an exhaustive data collection campaign. Therefore, the EB method is applied using only geometrical and demographical attributes that are directly and indirectly linked to traffic flow.

In order to validate the expected number of crashes predicted with the EB method using only geometrical and demographic characteristics, traffic counts were performed at an average of 3 % of all the sites in the region. The sites with similar characteristics have been grouped together. Intersections and road segments were grouped into seven and five groups, respectively. The grouping of intersections was based on a hierarchy of the roads arriving to the intersection (first criterion) and the density or type of land surrounding the intersection (second criterion). The hierarchy used is: 1) any road from the superior (MTQ) network; 2) rural arterial; 3) urban arterial; 4) urban local road; and 5) rural local road. The density cut-off of 150 inhabitants/km^2 value was set based on the Organisation for Economic Co-operation and Development (OECD) which takes into account the rural living environment of the municipality, especially in distinguishing within the same region people living in the countryside and in small towns from those living in more urban environments (*20*). The type of land surrounding the intersection was separated in two categories: urban and other (i.e., agriculture, wood land, etc.). The sites that were collected for each group were chosen randomly and their spatial distribution was taken into consideration, in order to avoid collecting sites only in one area. The estimated number of crashes using the EB method with and without traffic counts (on the subset of sites with counts) showed that the results were very similar and that the EB estimates without traffic counts could be used for the rest of the study.

Two SPFs were calibrated for the sites in the region; one for intersections and one for road segments as shown below (see also Table 2 for coefficients definition).

For intersections:

$$SPF = \beta_0^{0.337804} \times e^{(-1.352688-0.6913148\times\beta_1+1.422848\times\beta_2+1.055499\times\beta_3+1.337946\times\beta_4+0.7676198\times\beta_5)} \quad (2)$$

For road segments:

$$SPF = \beta_0^{0.3551079} \times \beta_1^{2.167077} \times e^{(-3.761083+1.145564\times\beta_2-1.188895\times\beta_3)} \quad (3)$$

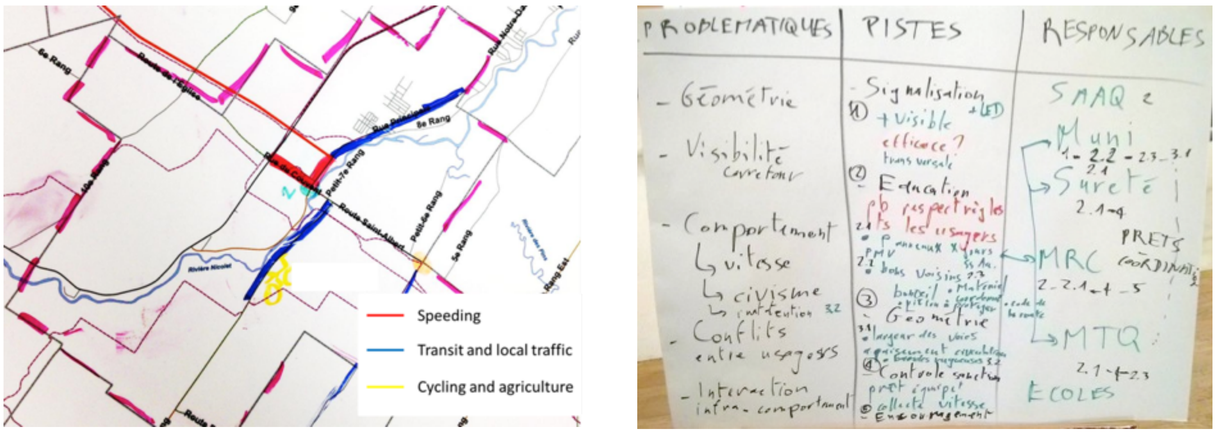
TABLE 2 Safety performance function for intersections and road segments

	Coefficient	Definition	Type	Standard deviation	95% confidence interval	
Intersections	β_0	Density	Numeric	0.0224	0.2937	0.3818
	β_1	Type of intersection: T type	Binary	0.0905	-0.8687	-0.5138
	β_2	Intersection MTQ/Municipal	Binary	0.1148	1.1978	1.6478
	β_3	Presence of pedestrian crossing	Binary	0.1413	0.7783	1.3326
	β_4	Exclusive right turning lane	Binary	0.2248	0.8973	1.7785
	β_5	Land use: agriculture	Binary	0.1287	0.5153	1.0198
			Constant	0.1654	-1.6770	-1.0283
Road segment	β_0	Density	Numeric	0.0277	0.3007	0.4094
	β_1	Number of lanes	Numeric	0.2887	1.6011	2.7330
	β_2	Paved	Binary	0.1605	0.8308	1.4603
	β_3	Type of road: urban local road	Binary	0.1183	-1.4208	-0.9569
			Constant	0.2423	-4.2360	-3.2860

The SPF for intersections shows that the expected number of crashes increases as the density increases. Geometric characteristics such as pedestrian crossings exclusive and right turning lanes also tend to increase the expected number of crashes. Furthermore, an agriculture land use and intersections having at least an approach from the superior road network also increase the expected number of crashes. Finally, the only characteristic that decreases the expected number of crashes is the type of the intersection (T-intersection). Since the number of expected crashes is estimated on road segments that vary in length, the length is used as a measure of exposure in the SPF. The road segment SPF shows that the four attributes that have a statistically significant association are the population density, the number of lanes, paved roads, and urban local roads. All of the characteristics increase the expected number of crashes except for urban local roads.
Once calibrated, the SPFs were used in the EB method to identify accident prone intersections and road segments. The expected number of crashes estimated by the EB method for each site was compared to the mean expected number of crashes plus one standard deviation of the expected number of crashes in the aforementioned group the site belongs to.

Step 3: To initiate a consultative process with local road safety stakeholders

The consultation process was put in place at the very beginning of the pilot project and was divided in three phases. First, a local press review was performed to find all the municipal-level stakeholders involved in road safety and transportation (*21*). Overall, more than 40 stakeholders have been identified and invited to participate. The second activity consisted in individual interviews with one of the researchers between October 2012 and February 2013: this interview was done in the presence of a single agency/partner, but several participants from the same organizations attended. As part of this interview, participants were interviewed about their concerns in terms of risks per type of road user, the function of roads and the land use. Participants were also given a map of the RCM and asked to draw where their main concerns about road safety on the network were. Color markers were used to identify road segments and intersections with different categories of issues: speed, lack of infrastructure, etc. The third activity consisted of a one-day workshop (six different activities) held in September 2013 and aimed at: i) validating the issues highlighted during individual interviews, ii) reaching a consensus on the order of priorities within smaller groups of participants (8-10 in each group) and iii) suggesting practical courses of actions to meet those priorities. It is important here to acknowledge the help of the RCM for the recruitment phase: a very good partnership that was in place from the start helped to reach a lot of people from different areas of the RCM and fields of expertise and had a positive influence on the consultation process. Overall, 27 organizations (50 participants) took part in the interviews and 21 organizations were present at the workshops (27 participants). Municipalities were the most common type of organization: 20 of the 23 municipalities in the RCM (87.0 %) participated to at least one activity of the consultative process; they represent 70.4 % of the organizations met during the interviews and 57.1 % of the organizations attending the workshops. FIGURE 1 illustrates examples of outcomes obtained during interviews and workshops.



a) Maps drawn during nterviews **b) Workshops***

*Translation of the three columns: *issues, course of action, stakeholders that could be in charge*

FIGURE 1 Examples of outcomes from the consultative process

TABLE 3 summarizes the ten most important issues for the stakeholders. This list is based upon a systematic content analysis of the *verbatim* (transcribed interviews and workshops) and is at the core of the comparative analysis presented later. The most cited issues in interview were "speed" (26 of 27 organizations), "conflicts between transit and local traffic" (n=24), and "road signage" problems (n=23). Content analysis reveals that the municipalities tend to insist more on the infrastructure, geometry and TCD issues, all related to municipal infrastructure investments while other organizations insist on human factors and issues that are related to enforcement and education policies, which are mostly part of their mandate. Some differences emerge between municipalities: lowland municipalities mentioned in priority problems of infrastructure, dangerous behaviours (speed and impatience) and conflicts between the road users (for example, when a tractor exits on the road to reach another agricultural field on the other side of the road). Highland municipalities raised issues about geometry of the road segments and intersections (maintenance and necessity to pave some rural road used as shortcuts) and about road users' conflicts with heavy vehicles. Finally, larger municipalities insisted on the need to improve the consistency of geometry and TCDs, and the manifold conflicts between all road users (pedestrians, cyclists, trucks and automobiles). More specifically, the conflict between transit and local traffic is perceived as problematic in a context of urban growth in neighborhoods that were not built for such level of traffic. The increased congestion during rush hours (especially in Victoriaville) encourages road users to choose shortcuts to avoid traffic on arterials and collectors and creates problems elsewhere on local roads.

TABLE 3 Most salient issues (most recurring during interviews and workshop)

Code	Themes/Issues (unranked)	Corresponding variable in the accident database
Road signage	Non-compliance to road signs and markings (Traffic Control Devices, TCD) with respect to the safety standards for all road users and lack of consistency across the network	Crashes located near an intersection with *missing markings or signs* in one or more approaches
Wildlife	Collisions with wildlife	Crashes involving *animals on the road*
Village Entrance	Inadequacy of village entrance configurations encouraging the violation of speed limits	Crashes located in a *300 m radius of the urban limits reporting a problem of excessive speed*
Geometry	Mismatch between road geometry, signs and dangerous driving	Crashes located in a *300 m radius of the urban limits reporting a combination of excessive speed or deficient infrastructure/ dangerous geometry/bad visibility*
Transit and local traffic	Conflicts between transit and local traffic	Crashes involving at least *one driver not living in the RCM or crashes near a residential entrance/exit directly on a road*
Rural vehicles	Conflicts between road users on rural roads, particularly agricultural vehicles	Crashes located in an *agricultural or wood land area*
Pedestrians	Inadequacy of the pedestrian network (non-existent, lack of space, connectivity problems)	Crashes located in an *urban area, involving at least one pedestrian*
Cyclists	Inadequacy of the cycling network (repair, design, signs, lack of facilities)	Crashes located in a *100 m radius of a bike path, involving at least on cyclist*
Speed	Non-compliance with speed limits	Crashes caused by *excessive speed*
Trucks	Conflicts involving heavy vehicles	Crashes involving *at least one heavy vehicle*

Step 4: To compare results from the EB analysis to the information gathered from stakeholders

In order to explore the advantages of the EB method versus stakeholder knowledge to determine APLs, two complementary analyses were performed: a *thematic* and a *spatial* comparison.
First, issues raised by participants during interviews and endorsed at the workshop were associated to variables present in the accident database (see Table 3 for the complete list). Accordingly, a severity index (also called the equivalent property damage only index in the Road Safety Manual) (*22*) has then been calculated for each issue, defined as the average severity of crashes weighted according to their severity (the more crashes are serious, the higher the weight):

$$I_g = \frac{9.5 \times N_{mortal\ or\ severe\ injury} + 3.5 \times N_{light\ injury} + N_{PDO}}{N_{all\ severities}} \tag{4}$$

where $N_{severity\ level}$ is the number of accidents of given severity level(s): mortal or severe injury; light injury; and property damage only (PDO).

Secondly, accident sites, intersections and road segments' APLs drawn during interviews or derived from the EB analysis were superimposed using two grids: one covering all the RCM, with pixels of 500 m^2, and one covering Victoriaville only, with pixels of 250 m^2 each in order to distinguish more precisely APLs in the urban core. Attributes from the three original layers were then added to each grid by spatial linkage: as soon as an intersection or a road segment was falling inside a pixel, the pixel was counting it, adding all of them in each pixel. Maps were drawn from these attributes to explore spatial similarities. Finally, Pearson correlation coefficients were calculated to measure the type, intensity and significance of the relationship between these three layers.

RESULTS

Thematic and systemic issues raised by stakeholders and accident data

The ten most important issues for the stakeholders were present in 73.2 % of the crashes. A bit less than 80% of mortal and severe injury crashes are associated to at least one issue, while this proportion is respectively 74.7 % for crashes with minor injuries and 72.8 % for property-damage-only crashes. This illustrates the stakeholders' good knowledge of issues related to road safety and supports the credibility of the consultative process.

Issues most cited by stakeholders (excessive speed, transit/local traffic conflicts and road signage problems) account for a fair share of crashes, respectively 951 (18 %), 3020 (58 %) and 1660 (32 %) collisions (Table 4). The total of these three most cited issues sums up to 4487 collisions, which represent 86.6 % of all the crashes. These issues appear as transversal and of interest for all.

The rest of the issues have a lower number of crashes associated to them, which is consistent with the real numbers anyway: the cyclist and pedestrian issues represent only 7 + 112 crashes (2.3 % total), while rural road users cohabitation and wildlife, two issues raised by rural participants, are associated to 404 + 366 crashes respectively (14.9 %). However, these issues raise specific problems stakeholders are very preoccupied with. Unsurprisingly, the highest severity indices are observed for users that are the most at risk: pedestrians (3.72) and cyclists (2.57). Conflicts with rural vehicles are also characterized by a high severity index, in part of the speed and the vulnerability of other road users (2.25).

TABLE 4 Crashes per severity according to stakeholders' issues

	PDO		Minor injuries		Major and fatal injuries		Total		Severity index
Issues*	**#**	**%**	**#**	**%**	**#**	**%**	**#**	**%**	
Road signage	1371	32.1	253	30.7	36	41.4	1660	32.0	1.57
Wildlife	330	7.7	35	4.3	1	1.1	366	7.1	1.26
Village Entrance	407	9.5	81	9.8	8	9.2	496	9.6	1.55
Geometry	1103	25.8	266	32.3	32	36.8	1401	27.0	1.67
Transit and local traffic	2613	61.2	383	46.5	24	27.6	3020	58.3	1.38
Rural vehicles	265	6.2	113	13.7	26	29.9	404	7.8	2.25
Pedestrians	19	0.4	81	9.8	12	13.8	112	2.2	3.72
Cyclists	5	0.1	1	0.1	1	1.1	7	0.1	2.57
Speed	751	17.6	179	21.7	21	24.1	951	18.4	1.66
Trucks	359	8.4	54	6.6	3	3.4	416	8.0	1.39
Total	**4271**	**100**	**823**	**100**	**87**	**100**	**5181**	**100**	**1.54**

*Total for all the issues exceeds the total number of accidents because one crash can be attributed to more than one issue.

Spatial comparison of APLs

The geographical distribution of accidents across the RCM shows a high concentration of crashes in urban centers, especially in Victoriaville (FIGURE 2). Crashes in the municipalities in the lowlands (northwest of the RCM) are more scattered but remain important, while the number of crashes in the highland municipalities (south-eastern part of the RCM) is lower. More than 75 % of all crashes on the municipal road network are located within the limits of Victoriaville, although they are less severe, as measured by the severity index. In fact, many severe injuries and fatalities are observed mostly outside the urban centers to the south, northwest and around Victoriaville, mostly on rural municipal roads.

The APLs determined from the EB method seem to have a similar distribution as the one for accident data: it is especially visible for Victoriaville and the adjacent municipalities. This is not surprising since the method heavily relies on accident data. The APLs determined from the interviews with stakeholders show similarities with the APLs identified by the EB method. Both methods tend to determine APLs where the most severe crashes occur. However, the rural road segments are more salient and distributed across the RCM than the EB method.

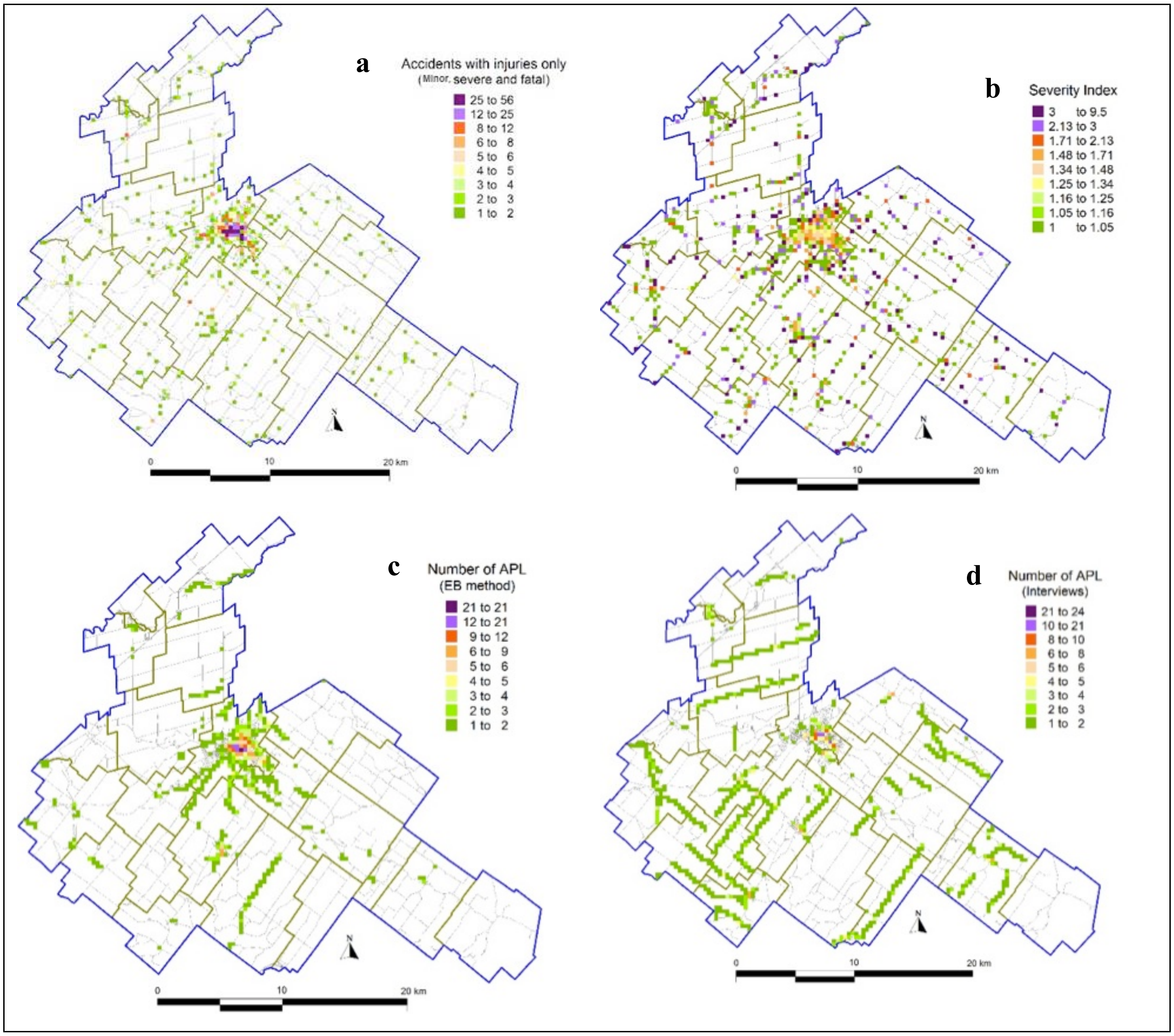


FIGURE 2 Spatial distribution of a) Accidents; b) severity index; c) EB APLs; and d) Interviews APL

Results of Pearson's correlations are shown in Table 5 for the whole RCM (top) and for Victoriaville (bottom). For the RCM, the APLs from both EB method and the interviews have positive relationships with accident data. APLs from EB method are highly correlated with PDO and injury crashes (respectively 0.705 and 0.698). To a lesser extent, APLs from the interviews are also significantly correlated to PDO crashes (0.538) and to all-injury crashes (0.534). In contrast, APLs from interviews are negatively associated with the severity index. This tends to show that stakeholders rely less on factual accident severity to determine "their" APLs. The severity index is also weakly associated to the APLs from the EB method. One reason may be the low number of fatal crashes in the crash data over the period of study (2007-2011), while it gets an important weight in the computation of the index. For Victoriaville only, using four more detailed grid squares (half the width of the square for the RCM), similar positive relationships are observed, but with some differences. Here, APLs from interviews are more correlated to accident data, for all injury accidents and all accidents (respectively 0.663 and 0.644). The APLs from the EB method are correlated to a lesser extent (0.48 for all injury and 0.49 for all accidents). The important number of pixels identified as APLs in the Victoriaville area may explain why the relationship between EB results and accident data is slightly lower than the correlation across the RCM. Again, the severity index has little to no association with the APLs, independently from their method (EB or Interviews). In the end, EB and interviews have positive correlations of moderate intensity across Victoriaville (0.401) and across the entire RCM (0.301). This tends to illustrate that the two APLs methods are rather complementary than contradictory.

TABLE 5 Correlation matrix of APLs and Accident data for RCM ($500m^2$) and Victoriaville ($250\ m^2$)

		All crashes	PDO	Light	Severe	Fatal	All injured	Severity index	APLs (EB)	APLs (Interviews)
RCM	**All crashes**	1	0.999	0.954	0.528	0.131	0.951	0.081	0.705	0.538
	PDO		1	0.938	0.511	0.121	0.934	0.063	0.698	0.534
	Light			1	0.54	0.154	0.996	0.154	0.705	0.53
	Severe				1	0.091	0.603	0.372	0.451	0.32
	Fatal					1	0.187	0.22	0.105	0.09
	All injured						1	0.187	0.709	0.532
	Severity index							1	0.118	-0.115
	APLs (EB)								1	0.301
	APLs (Interviews)									1
	*For the RCM, All correlations are significant at the 0.01 level (2-tailed)									
		All crashes	**PDO**	**Light**	**Severe**	**Fatal**	**All injured**	**Severity index**	**APLs (EB)**	**APLs (Interviews)**
Victoriaville	**All crashes**	1	0.998*	0.903*	0.424*	0.112*	0.904*	0.096*	0.492*	0.644*
	PDO		1	0.872*	0.408*	0.099*	0.873*	0.077	0.485*	0.630*
	Light			1	0.406*	0.144*	0.996*	0.176*	0.483*	0.670*
	Severe				1	0.103*	0.482*	0.372*	0.210*	0.247*
	Fatal					1	0.179*	0.115*	0.060	0.049
	All injured						1	0.206*	0.482*	0.663*
	Severity index							1	0.024	0.095*
	APLs (EB)								1	0.401*
	APLs (Interviews)									1
	* For Victoriaville, only flagged (*) correlations are significant at the 0.05 level (2-tailed)									

The mapping of the pixels determined as APLs either from the EB method, from the interviews or from both is represented in FIGURE 3. Across the RCM, 1020 pixels ($500m^2$) have at least one APL according to one of the methods: 104 (10.2 %) with the two methods, 315 (30.9 %) for the EB method only and 601 (58.9 %) for the interview only. Across Victoriaville only, 399 pixels are either determined by EB, or interviews, or both. The proportion of pixels with at least one APL according to both methods is of 18.5 %, the EB method identifies 76.9 % and interviews only 4.5 %. The spatial visualisation of the two methods' complementarity is rather clear in this figure. Both methods have determined similar APLs in the urban area of Victoriaville. While the EB method underscores APLs in the municipalities adjacent to Victoriaville, the interviews underscore problematic roads and intersections in rural areas, especially in the western and southern part (lowlands) of the RCM.

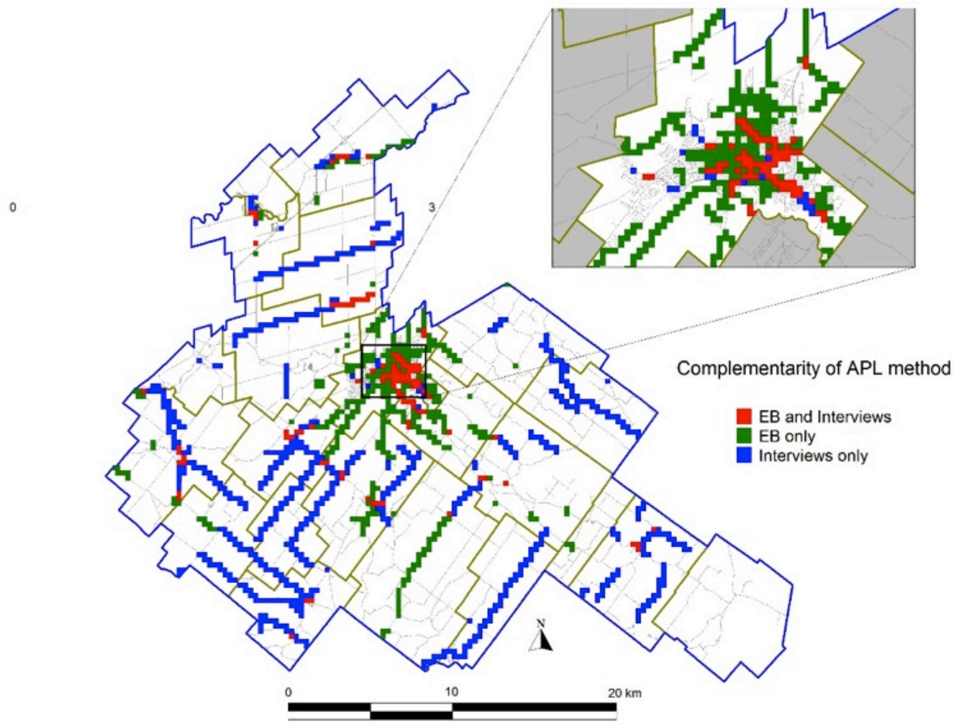


FIGURE 3 Overlay of APLs determined by the EB and Interview methods

DISCUSSION

This paper has presented a four-step methodology to perform a road safety diagnosis and determine both systemic issues and APLs in predominantly rural areas. The first step was to implement a spatial database, which consists of collecting all the data available and relevant to road safety, from accident data and the road network to census, environmental data and traffic flow and speed data. The second step was to estimate the expected number of crashes, based on the observed number of crashes and the characteristics of the sites prone to increase or decrease the expected number of crashes (traffic flow, road geometry and signals, number of lanes, pavement etc.). To complement and nuance the statistical results given the lack of traffic flow, the third step consisted in initiating a consultative process with local road safety stakeholders. The fourth and final step compared the results obtained at step 2 and step 3 with the accident data. The most important perceived issues have been linked to accident characteristics and spatial correlations have been calculated across the regional municipal county of Arthabaska.

Results illustrate the viable alternative of incorporating the stakeholders' input in the method of analysis. First, it shows that using the stakeholders as a source of additional information for a road safety analysis is worth the effort. The ten perceived most important systemic issues cover 73.2 % of the crashes of the database, and the proportion seems to get higher with the severity of crashes.

Second, engaging stakeholders in a road safety analysis gives an opportunity to reinforce the real perceived issues, while bringing some nuance and further details. The analyses show that the most cited issues such as excessive speed or the conflicts between transit and local traffic have also a large share of crashes. These issues can be viewed as transverse or systemic, as they not necessarily involve severe crashes, but raise recurring problems. In contrast, some issues such as road users' conflicts involving cyclists or pedestrians pertain to a lower number of crashes, but the risk perception related to these issues is very high. These biases may be explained by the higher severity of such accidents and the greater vulnerability of non-motorized road users. The sample of accidents for each raised issue could be examined in more details to confirm the hypotheses underlying those perceptions. The quantity of attributes, such as the road characteristics, the period of time when the crash occurs, the description of the vehicle users, or the type of impact, could bring a better understanding of the situation. In some cases, a systematic review of the perceived issues with the accident data could also nuance some of them. Causes of these misleading perceptions could be external events, such as excessive media exposure of certain types of accidents. Or, they could also be a hint of emergent issues found in the analysis. In this case study, the analyzed accidents were comprised between 2007 and 2011, whereas the interviews and workshops were held in 2012 and 2013. The stakeholder input provides an insightful perspective on the most recent issues they are facing in their everyday life and political agenda. Yet, the influence of the recent crash history of crash may also explain the discrepancies between objective and subjective data and should be further investigated.

Finally, engaging stakeholders gives a context-based and complementary view to re-interpret the objective accident data that, even if scattered across a rural region, provide a considerable amount of information to be collected, structured and analyzed. The mapping of the perceived APLs, and their overlay with the accident data and APLs from the EB method, confirm the relevance to incorporate stakeholders' input and judgement in a preliminary step of decision-making. The statistical correlations between the accident data, the EB method and the interviews with the stakeholders show in most cases positive and significant relationships. Whereas the EB model helped to determine APLs in sites where traffic flow (and usually the number of accidents) are higher, interviews enables to identify APLs in more scattered rural areas, predominant in the study area.

In the future, to reduce the time and effort to integrate stakeholder views in road safety analysis, a shared online map could be especially useful for stakeholders to consult the history of crashes as well as to give their feedback on past, present and possible safety interventions. The next step of this research will be to recommend a general method to identify APLs on rural and local roads in Quebec. Creating opportunities for stakeholders to interact on a regular basis, in person or through shared online resources could reduce the gap between their perceptions and objective safety, as well as address road safety issues in a multi-level continuous improvement process.

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