Identification of Dangerous Highway Locations: Results of Community Health Department Study in Quebec

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Dangerous highway locations on numbered highways within the territory of one community health department are identified. Three sources of information are used: police accident reports, a systematic inspection of all numbered highways, and a community survey of municipalities, police, and health service providers. The location of all police-reported fatal and serious-injury accidents were reviewed and corrected, and corrections were submitted to the reporting jurisdiction; this resulted in a 20 percent increase in the number of these reports attributed to numbered highways. The initial police-reported data included 11,538 accidents with and without victims occurring on the 271 km of numbered highways in the territory between 1984 and 1987. A weighting system based on the severity of injury for each police-reported injury was used in the initial screening process; the influence of differing weighting schedules using corrected and uncorrected location data is presented in a matrix. Weighted injury frequencies per unit distance and weighted injury rates per 100 million vehicle-km are presented for all sites and for all numbered highway segments. Priority sites are ranked considering injury frequencies and injury rates. The convergence of identification by police-reported data, by highway inventory, and by community reporting is presented. The 28 priority sites retained for further study cover about 6 percent of the numbered highways in the territory but account for 53 percent of deaths, 30 percent of serious injuries, and 32 percent of minor injuries from accidents reported by police.

Community health departments (DSCs) in Quebec have been working in the field of highway safety since the early 1980s. At the Sixth Canadian Multidisciplinary Road Safety Conference, the departments in the Monteregie area of Quebec presented an overview of their work on identifying dangerous highway locations in their region (*1*). We now report the final results of this work in greater detail for the territory of one of the four participating departments.

The identification and correction of hazardous highway locations have received a great deal of attention across North America over the past 25 years; it is particularly evident in the engineering literature. Reviews of methodology for this work are available as well as recent reviews of the relationships between specific highway infrastructure elements and the frequency of roadway-associated accidents and the severity of associated injuries (*2–5*). Travel-lane width, shoulder width and surface condition, sideslope characteristics, and highway geometry, particularly the presence of curves, have been related to injury severity and frequency. Administrative regulations requiring the identification and correction of dangerous highway locations in the United States have been defined by federal law since 1966. Cost-effectiveness and cost-benefit analyses have been proposed to guide highway rehabilitation programs with respect to infrastructure elements (*6*). Methodologic issues have recently received more attention, particularly concerns about the need to correct for regression-to-the-mean phenomena when the evaluation of intervention effectiveness is done for "dangerous locations" (*7*).

In Quebec during the past 6 years, more than 10 studies identifying dangerous highway locations have been published by DSCs and university groups. With the exception of one study on bridge accidents, we know of none published in indexed peer-reviewed journals. The Ministry of Transport in Quebec has also been concerned by this subject and in 1990 announced a funding program for the correction of dangerous highway locations.

Inadequacies of the localization methods used in police reports in Quebec have been identified repeatedly. The coordinate localization is based on "mercators," 1- × 1-km squares defined by longitude and latitude numbers; this is the standard computerized localization method used by police in Quebec. In 1987 the Ministry of Transport announced its intention to introduce a link-node identification system for accident localization; this project has since been transformed into a project localizing sites using satellite-based technologies.

We present the methodology and results of our hazardous highway localization work developed from a public health perspective applied at a local level. We view this method as a screening tool for the presumptive identification of unrecognized (or at least uncorrected) dangerous highway locations (*8*). In much the same sense as medical screening tests, the "cases" being identified (in this discussion, dangerous highway locations) need further investigation before the initial diagnosis is confirmed or rejected. As in all screening tests, some cases will be identified falsely as being dangerous sites (false positives) and some dangerous sites will not be identified (false negatives). We must emphasize that a screening test is not diagnostic and represents only an initial examination that must be followed up by more investigation. The evaluation of the ability of a screening test to discriminate between cases and noncases is dependent on a "gold standard" that identifies cases with and without the condition being studied. The prevalence of the condition in the population will influence the predictive value of the test in the study population.

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In addition, the usefulness of a test will depend on a series of defined factors that include the importance of the condition (in terms of costs and suffering), the availability of effective treatment for identified cases, and some knowledge that the early identification (before the condition becomes symptomatic) of the condition will benefit the patient or society. The analogies for the case of dangerous highway locations are clear, but the absence of a true standard against which presumptive cases are judged remains a practical problem. We have dealt with this by choosing a somewhat arbitrary cutoff point, selecting only the "most extreme" cases in our population.

STUDY AREA

The geographical area examined by this study is on the south shore of the St. Lawrence River near Montreal and covers an area of about 100 × 20 km; 438,000 people live in the area. It is part of a larger administrative territory, the Monteregie, for which we present police-reported motor vehicle mortality data in Table 1.

In Table 1 we compare estimates of rates of death per 100 million vehicle-km of travel on our region's highways with those on U.S. highways. The U.S. data include 100 percent of motor vehicle–related deaths occurring in the United States as reported by the Fatal Accident Reporting System. We would like to underline two points:

1. The death rate increases with decreasing infrastructure quality for the numbered highways.
2. Most deaths associated with roadway use occur on numbered highways. In the case of the U.S. data, 57 percent of deaths occur on 22 percent of the total roadway distance.

Interpreting Table 1 to indicate that highways in the Monteregie are "worse" than those in the United States because death rates for each roadway category are higher in the Monteregie should be done with caution. It should be noted, however, that when these data were collected, rates of seat belt use were about three times higher in Quebec than in the United States. If all other factors were equal, and if seat belt use does effectively reduce the likelihood of death, one should expect lower death rates on Monteregie roads. It would be quite simple and inexpensive to use the methodology presented in this paper to determine the quality of highway infrastructure in different jurisdictions.

On the basis of our interpretation of Table 1—using in part the logic attributed to Jesse James when asked why he robbed banks ("Because that's where the money is")—this study is limited to the identification of hazardous highway locations on numbered highways. The rest of the paper deals with the data on numbered highways given in Table 2.

Information about the 271 km of numbered highways was thus examined. In the 4 years of reporting, 11,538 accidents were reported on these highways, of which 2,232 were accidents with victims. These represent 29 percent of all reported accidents, 58 percent of all deaths, and 38 percent of all severely injured victims in our territory.

METHODOLOGY

The definition of hazardous highway locations used in this study is that proposed by Zegeer: "highway spots, intersections or sections with an abnormally high accident experience (frequency, severity or rate) or potential" (*2*).

The operational definition included all of these elements, that is, frequency, severity, rate, and potential for injury. The first three elements were derived from police accident reports and highway traffic flow and distance data available for all highways in our area (*9,10*). Treatment of these data is further defined later in the paper. The fourth element, accident potential, is derived from the systematic visual inspection of the 271 km of numbered highways using a methodology based on a report by Zegeer and further described later in the paper (*3*).

In addition to the accident report and highway inventory methods, we addressed a community survey questionnaire to all municipalities, community clinics, ambulance services, and municipal and provincial police in our area. They were asked about their perceptions of the importance of dangerous highway locations and the identification of specific sites. This methodology is also further described later.

To the best of our knowledge, this is the only report of such a combined identification methodology. Innovative fea-

TABLE 1 Motor Vehicle–Related Fatality Rates for United States (1985) and Monteregie (1984–1987)

Highway category	Total number of deaths		Fatality rate per 10^8 veh-km	
	USA	Monteregie	USA	Monteregie
. Interstate	4 200	118	0,7	0,9
. Principal	14 200	235	1,7	2,7
. Secondary	6 500	130	2,5	3,8
. Unnumbered	18 900	334	1,6	N/A
Total	43 800	819		

Source: TRB (4) and calculations by community health departments from MTQ and Quebec Automobile Insurance Society Data (SAAQ).

TABLE 2 Distribution of Motor Vehicle Injury Victims by Severity of Injury and Category of Highway Site of Injury, Territory of DSC Charles LeMoyne, 1984–1987

Highway category	Highway length (km)	Number of victims		
		Deaths	Severe injury	Minor injury
. Interstate (# 0 - 99)	109	35	113	857
. Principal (#100 - 199)	122	60	407	2 267
. Secondary (#200 - 299)	40	6	46	294
Total	271	101 (58%)	566 (38%)	3 418 (26%)
. Entire territory	Not available	175	1 483	13 000

Source: Quebec Automobile Insurance Society, Ministry of Transport of Quebec.

tures include the use of corrected localization data for all fatal and severe-injury accidents, the use of a severity index including only injury accidents, and the integration of these methods for selection of priority sites for further evaluation.

Accident Report–Based Methodology

Data Collection

All police-reported injury accidents were initially examined using a computerized data base. The location of fatal and severe-injury accidents (1,359 accidents, 1,658 victims) were corrected for the highway number and for the mercator number. As shown in Table 3, this resulted in a 20 percent increase in the number of reports attributed to numbered highways (from 438 reports before correction to 526 reports after correction). This is primarily due to the use of highway names without the corresponding number in some reports, particularly for highway sections passing through highly urbanized areas. The number of accidents occurring on numbered highways with both highway number and mercator identified increased by 88 percent (from 267 to 503 after correction). Nineteen percent of all fatal and severe-injury accident reports were corrected; mercator numbers were corrected only for reports attributed to numbered highways.

After corrections, a computer printout of all corrected reports was submitted to the police department responsible for having completed the report. Twenty-one police departments were contacted, and they confirmed, with few exceptions, the appropriateness of our corrections.

Data Treatment

As a screening tool developed from a public health perspective, we chose to use injury victims as our unit of analysis. Most engineering literature reports use accidents, sometimes stratified by severity, as the unit of study. It is our understanding that the difference in the two units will be most evident in the case of severe frontal collisions; our method will in general attribute greater importance to these collisions because, for a given accident severity, the frontal collision will generate more victims than, for example, a single-vehicle fixed-object collision of equivalent accident severity. In effect, a single severe-injury accident that generates three severely injured victims will be counted three times in our system but only once in a classic engineering study.

An injury severity index that permitted the use of a single numeric value to express the total cost of all injuries associated with a particular location was applied. The values chosen were related to the direct and indirect economic costs of injuries as determined by the Quebec Automobile Insurance Society (*11*).

Fatal injuries were relatively undervalued in this system relative to Quebec economic cost data and costs based on other methodologies (*11–14*). The values attributed for different injury severity are as follows:

TABLE 3 Corrections Made to Accident Reports for Fatal and Severe-Injury Accidents, Territory of DSC Charles LeMoyne, 1984–1987

	Highway number present		Highway number absent		Total
	Mercator number		Mercator number		
	Present	Absent	Present	Absent	
Before correction	267	171	235	692	1 365
After correction	503	23	227	606	1 359

- Fatal injury—100
- Severe injury—20
- Minor injury—3

The weighted injury frequency for a particular location is calculated as the sum of the number of victims of a given severity (*Ni*) multiplied by the corresponding severity (*Si*), repeated for each severity level:

$$\text{weighted frequency} = \sum_{i=1}^{3} Ni \cdot Si \qquad (1)$$

The weighted frequency for highway sections (from 12 to 47 km long) for each of the 12 numbered highways in our territory were also calculated as weighted frequencies per kilometer of roadway. Weighted injury frequencies were calculated for each of the mercators through which numbered highways passed.

We examined the influence of using corrected and uncorrected highway location data as well as the significance of the choice of severity index. This was done by comparing the 50 highest weighted frequency mercators that would be selected by using each of four different weighting schemes and comparing before-correction data with after-correction data. These comparisons are presented as a correlation matrix in Table 4.

The correction of location data alone resulted in a minimum of 9 (18 percent) and a maximum of 22 (44 percent) of the 50 mercators' changing. In our complete report we have also shown that between 10 and 34 percent of the 50 highest-frequency mercators change solely on the basis of the use of different weighted injury frequency scales (i.e., different severity indexes) (*15*).

The process of identifying individual hazardous sites using accident reports was done in two stages. The first stage involved selecting mercators with both high weighted injury rates and frequencies. In the second stage, data for these mercators were examined to identify specific sites (e.g., intersections) within the mercator, and these were retained as the sites for study. Victims from accidents occurring at the sites were identified and severity scores calculated. An intersection generally included 200 on each approach as attributed to the intersection.

Weighted injury rates for the 100 highest-value weighted frequency mercators were calculated by dividing the weighted injury frequencies by the vehicle-kilometers of travel for the 4 years of exposure. An estimate of 1.0 km as the length of numbered highway in each mercator was used for this calculation. Traffic volume estimates were those for 1986 applied to each of the 4 years: these were supplied by the Ministry of Transport of Quebec. Weighted rates are expressed as weighted frequencies per 100 million vehicle-km of travel. Figure 1 presents the results of the first stage in this selection process. Weighted rates and frequencies are plotted for the 100 mercators with the highest-weighted frequencies. This model of presentation is based on the work by Barbaresso in 1981 (*16*).

The consideration of injury rates and injury frequencies represents different and generally opposing perspectives for the identification of dangerous sites. Rates reflect a measure of risk for the individual roadway user for a given road; frequencies reflect the overall accumulated societal (collective) cost of injuries for a particular site. Rational investment of limited resources for maximal societal benefit will prioritize the examination of sites with high injury frequencies, all other elements being equal; however, considerations of equity and risk reduction for individual users require attention to limit disparities in rates. As seen in Figure 1, even though only the 100 highest-frequency mercators are included in the figure, high-frequency mercators are usually those with greater traffic volumes (i.e., Interstates and Routes 100 to 199) whereas high rate mercators are those with less traffic (Routes 200 to 400).

Using explicit criteria for both rates and frequencies, we identified 56 mercators in three priority groups for further study (Table 5). A fourth group of 44 mercators with weighted frequencies of less than 250 and weighted rates of less than 1,000 per 100 million vehicle-km were eliminated from further study.

The second stage of identification of specific sites within mercators was done by examining printouts of locations for injury accidents within each of the 56 mercators retained for study.

It was possible to identify specific intersections for many of these mercators, but in other cases this was not readily apparent. For those, the entire mercator was retained and identified as a dangerous section at this stage of analysis.

TABLE 4 Concordance of 50 Highest-Frequency Mercators Determined Using Four Injury Severity Indexes and Before- and After-Correction Accident Location Data

After correction \ Before correction	Severity index			
	Index 1 (10-9-3)	Index 2 (10-9-0)	Index 3 (100-20-3)	Index 4 (100-200)
. Severity index 1	41	32	36	32
. Severity index 2	29	28	27	27
. Severity index 3	35	33	36	35
. Severity index 4	29	29	32	32

Numbers shown are the number of concordant pairs for the 50 highest frequency mercators compared 2 at a time.
Numbers in parentheses refer to the index for (fatal - severe injury - minor injury) victims.

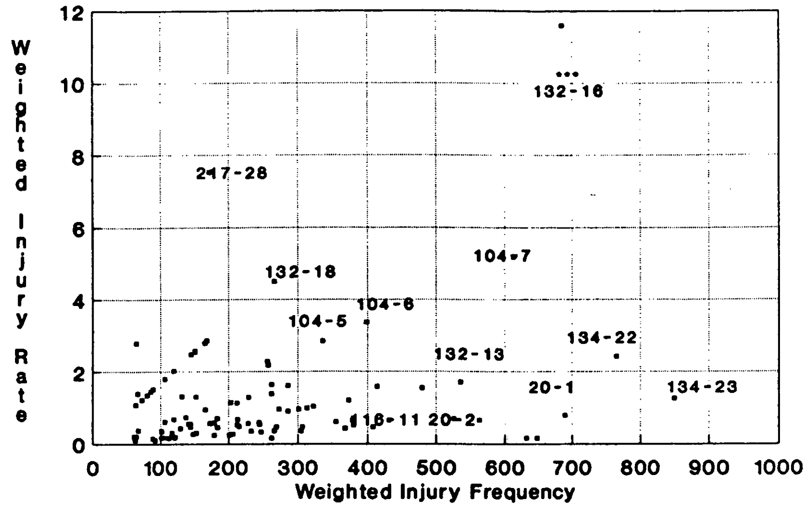


FIGURE 1 Weighted injury rates and frequencies for the 100 highest-weighted injury frequencies for mercators on numbered highways, territory of DSC Charles LeMoyne, 1984–1987 (*1*).

TABLE 5 Number of Mercators Retained for Further Study Identified According to Priority Group

Group	Number of mercators codes retained	Definition
. Priority 1	12	(1) X > 500; or (2) Y > 3 000; or (3) 350 < X < 500 and 2 000 < Y < 3 000
. Priority 2	23	(1) 350 < X < 500 and Y < 2 000; or (2) X < 350 and 2 000 < Y < 3 000; or (3) 250 < X < 350 and 1 000 < Y < 2 000
. Priority 3	21	(1) 250 < X < 350 and Y < 1 000; or (2) X < 250 and 1 000 < Y < 2 000

X = weighted injury frequency
Y = weighted injury rate

Highway Safety-Hazard Inventory

Zegeer et al. reviewed methods for the identification of hazardous highway elements (*3*). Principally on the basis of the model used by the Oakland County (Michigan) Road Commission presented by Zegeer et al., we developed a data collection form for the evaluation of the following roadway elements: fixed objects, guardrails, roadway geometry, signalization, and roadside characteristics other than fixed objects.

A hazard rating for fixed objects and the other characteristics, such as distance from the edge of the road, was defined on the basis of the Oakland study (*15*). Each element was assigned a numeric severity rating based on location and rigidity of the obstacles; ratings ranged from 3.0 to 9.3 and were reduced to three different categories:

- A—most hazardous with scores 7.5 to 9.3,
- B—intermediate level, and
- C—least hazardous, with scores of 3.0 to 4.8.

All 271 km of route were traveled and scored in both directions by two observers, one of whom did the same scoring for two other DSC territories. Identified highway hazards were photographed and a running commentary was tape-recorded to aid completion of the written observation coding sheet. Each hazardous element identified was coded into Categories A, B, or C. A report of hazardous elements for each numbered highway was prepared. Forty-five A-rated sites were identified using this method.

Community Survey

A community survey was mailed to the 21 local municipalities as well as to community clinics and regional administrations in 1986. Of the 29 respondents, 90 percent thought that the identification and correction of dangerous highway locations was important or very important. Respondents identified 83 sites that they considered dangerous or potentially dangerous; 38 of these sites were on numbered highways.

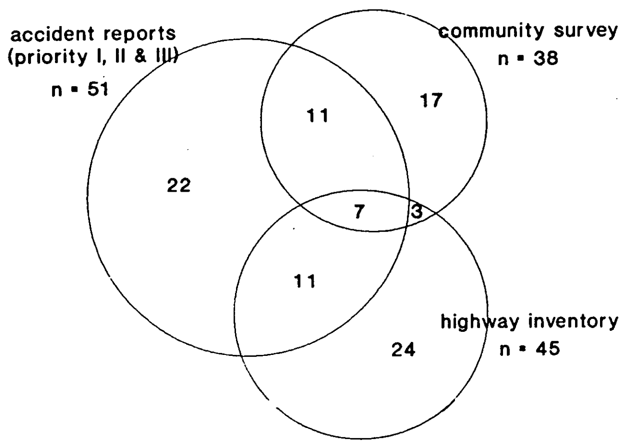
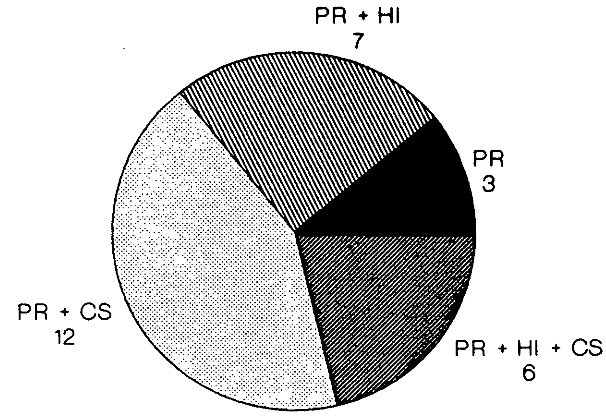


FIGURE 2 Method of identification of 95 potentially dangerous highway locations according to information source: Priority 1, 2, and 3 mercators identified from accident reports, the community survey, or the highway safety-hazard inventory.



PR = Police reports (priority I, II or III).
HI = Highway inventory.
CS = Community survey.

FIGURE 3 Distribution of 28 sites by method of identification, territory of DSC Charles LeMoyne.

TABLE 6 Criteria for Selecting Priority Sites

Criteria	Number of sites
All sites identified within priority 1 **mercators** (table 5)	12
All sites identified within priority 2 **mercators** (table 5) for which one or the other of the following criteria apply: . they have a highway inventory hazard code of A, or; . they were identified in the community survey	14
All sites identified within priority 3 **mercators** (table 5) for which both of the following criteria apply: . they have a highway inventory hazard code of A, and; . they were identified in the community survey	2

Integration Method for Selecting Priority Sites

Overall, the three methods identified 95 different sites on numbered highways. Figure 2 presents these sites according to the method by which they were identified. Most of the sites were identified by only one method; 32 sites (34 percent) were identified by two or three methods.

The criteria in Table 6 were applied to select the final 28 sites retained as priority sites. It should be stressed that all of the final sites identified as high priority were selected from the 56 mercators defined in Table 5.

RESULTS

The evaluation retained 28 sites as high priority for further study. Three sites were on interstates, 22 were on principal highways (numbered highways 100 to 199), and 3 were on secondary highways (numbered highways 200 to 399). The total combined length of the 28 sites is 17.6 km, or 6.3 percent of the 271 km of numbered highways studied. Fifty-four deaths, 169 severe injuries, and 1,084 minor injuries were attributed to these sites; these represent 53 percent of total deaths, 30 percent of severe injuries, and 32 percent of minor injuries attributed to the 271 km of numbered highways studied.

The methods of identification of the 28 sites are presented in Figure 3. Six sites were identified by all three methods. Seventeen sites are in rural locations, and 11 are in urban areas. All three interstate sites are at interchanges, and five of the sites on other numbered highways are at intersections. Eighteen other sites are defined as highway sections less than or equal to 1 km long and may include several intersections.

The weighted rates and frequencies of injuries for each of the 12 numbered highways included in the study are presented in Figure 4.

The hazardous features and injury experience attributed to each of these sections is presented in our final report. Frequently identified hazards include poorly maintained and poorly aligned guardrails, usually not in continuity with bridge abutments; poorly maintained highway shoulders; and deficiencies in highway geometry for some highways (particularly Route 104). Additional features are presented in our regional report (*17*).

DISCUSSION OF RESULTS

This study presents several features that we think deserve further attention. We are disturbed by the 20 percent increase in the number of fatal and severe-injury accident reports attributed to numbered highways after localization information was corrected. Small numbers of reports are involved, and one numbered route in an urban area contributed an important fraction of the total; nonetheless, in future use of police reports, particularly in areas in which numbered highways pass through larger urban areas, the underidentification of the importance of injury accidents occurring on numbered highways may represent a significant data treatment issue.

The deficiencies of the mercator system used in Quebec to localize accidents have been confirmed in this study; the number of fatal and severe injury accidents with mercators iden-

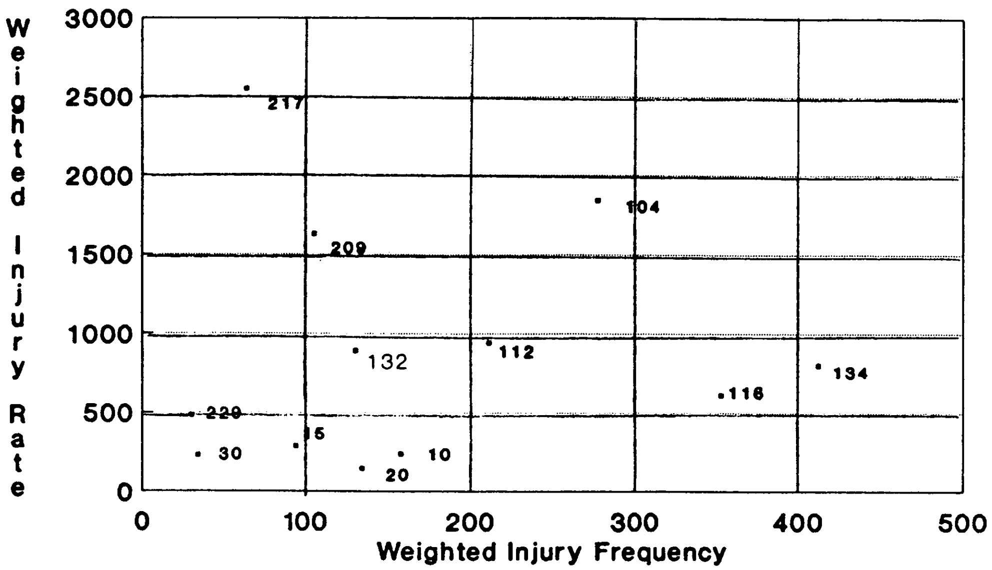


FIGURE 4 Weighted injury severity rates and frequencies for numbered highways, territory of DSC Charles LeMoyne (*Source: Quebec Automobile Insurance Society and Ministry of Transport of Quebec*).

tified on numbered highways was increased by 88 percent after our correction procedure. It should, however, be noted that our correction procedure was simple and inexpensive. Computer printouts of written location information are available for all reports, and we basically corrected the 1,300 reports in 2 days, after which printouts were sent to participating municipal and provincial police in our area. The process of working with police was positive. Thus, despite data inadequacies, corrections at a local level are generally quite straightforward at this level of precision.

We believe that our use of injury victims as the unit of analysis is innovative and has some advantages in accident severity counting, when viewing traffic safety from a public health perspective in the context of a screening study. These were discussed earlier. One disadvantage is the possibility of identifying false positives; for example, a single fatal accident involving six deaths would get undue attention.

The use of both frequencies and rates of injury is, we believe, a positive aspect of this study. The decision-making process used to establish priority groups was largely intuitive, however, and a more statistically sophisticated stratification decision analysis would be useful.

Our highway inventory methodology is quite straightforward and feasible for local highway analysis. We perceive the level of precision of our measurements to be low, although appropriate as a screening tool. We have had no evaluation of interobserver reliability nor of the validity of our measurements.

Our decision to limit the number of sites for further study to 28 was defined by our perception that a larger number would overload the capacity of local agencies to study the sites. This corresponds to the recommendation of the panel reviewing highway accident analysis systems; according to this report 1 man-year was required to analyze and review 170 sites for the California Department of Transportation in 1978 (*2*).

Overall, we think that the approach we have chosen is a useful pilot project that contributes to our ability to identify dangerous highway locations systematically. Work on this project was done over 4 years and involved four health departments without external funding. The total cost for the development and application of the method for the entire region (Monteregie) was less than $150,000 (Canadian), or about $9,000/year per health department; about one-third of costs were for development of the methodology, including the initial experimentation in one subregion of the Monteregie (*17*). The total contribution including development costs for the territory covered in this paper (DSC Charles LeMoyne) was about $32,000 (Canadian).

Since spring 1990 we have been working with the Ministry of Transport of Quebec, the Ministry of Municipal Affairs, local municipalities, municipal and provincial police, and elected municipal councillors in a pilot project studying all accident reports, including all material-damage reports, for the period 1986–1990 as well as remediable factors related to vehicles, human factors, and the roadway for eight sites across the Monteregie. The model used is based loosely on the Local Highway Improvement Program of FHWA with additional attention to human and vehicular factors contributing to injury frequency and severity (*18*).

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