Using Basic Collision Data to Manage Road Safety

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Abstract

In order to be applied, state of the art network screening methodologies require advanced statistical modeling techniques, and reliable traffic volume estimates and collision data for a period typically of at least three years. For those road agencies which lack the resources to apply these more advance techniques, this paper outlines a step-by-step analysis methodology which may be used to manage road safety using only historical collision data and tools no more advanced than a spreadsheet. The methodology is not new but this paper is the first to describe the analysis within a multi-disciplinary framework. By following this methodology, agencies will be able to take a more proactive approach to road safety management.

This paper works through the methodology by providing a simplified process for selecting emphasis areas for a jurisdiction as part of a safety management system. A further breakdown of collisions by emphasis area is used to identify the top areas of safety concern that require the involvement of engineering, enforcement, health, and education combined.

In addition, a more detailed analysis looks for the over-representation of different collision types by emphasis area allowing agencies to identify locations where specific collisions are occurring at higher proportions than would statistically be expected. Example calculations are provided to illustrate over-representation, which can then be applied to emphasis area collisions.

Introduction

This paper presents one way to tie together two major approaches, safety management and network screening, that during recent years are being implemented more and more often in Canada and the United States. The goal of both approaches is to improve safety in a jurisdiction, but whereas safety management may be thought of as a top-down approach, network screening is a bottom-up approach. That is, safety management starts with upper level management of various agencies working together to improve overall safety in a jurisdiction. Network screening starts with front-line decision makers identifying locations in a jurisdiction for site specific safety improvements. Both approaches may be used to address emphasis areas (areas of safety concern), as illustrated in Figure 1.

The goal of this paper is to outline a step-by-step analysis methodology which may be used to manage road safety using only historical collision data and tools no more advanced than a spreadsheet. In other words this paper is aimed at jurisdictions that recognize that they can benefit from a safety management plan but lack the resources to invest in developing one. This paper attempts to assist jurisdictions in developing the best possible safety plan with a minimal amount of effort and minimum data requirements. The methodologies presented in this paper are not new and neither are they the most advanced, but this paper is the first to describe the methodologies within a multi-disciplinary safety management framework.

Minimum Data Requirements

"Minimum data requirements" means the jurisdiction has following:

- a computer
- a database program such as Microsoft Access
- a spreadsheet such as Microsoft Excel
- historical collision data that is available in a database format for at least three years
- roadway inventory data available in a database format which should include information on intersections and roadway segments
- ability to link collision data to roadway intersections and/or segments

The last requirement, regarding linking collision data to roadway inventory information, refers to the ability to identify for every location which collisions occurred there.

Safety Management Systems Definition

This section presents a brief overview of one safety management system, the Integrated Safety Management Process (1). The Integrated Safety Management Process has the following components:

- Safety Program Leadership
- Operations Manager
- Risk Analysis and Evaluation
- Task Teams
- Process

The components of this organizational structure are discussed as follows.

Safety Program Leadership

The Safety Program Leadership coordinates the development and implementation of goals and supporting actions, facilitates the acquisition of needed resources, and provides support. The Safety Program Leadership should comprise all (or a majority subset) of the agencies with responsibilities for roadway safety. A Safety Program Leadership will most effective when it is made up of top-level management with the authority to make commitments and decisions. The success of a safety management system is entirely dependent upon having top management from each agency directly and personally involved in the Safety Program Leadership and having the authority to act on behalf of the stakeholder agencies.

Operations Manager

The Operations Manager is the safety champion responsible for directing daily activities, coordinating the efforts of various task teams, acting as the focal point for the safety management system, and providing the Safety Program Leadership with support in planning and implementing roadway safety improvements.

Risk Analysis and Evaluation

The Risk Analysis and Evaluation group conducts quantitative analysis and evaluation, and assembles additional safety information as requested by the Operations Manager, Safety Program Leadership, or Task Teams. The Risk Analysis and Evaluation group responsibilities cover two aspects of data and information management: the ability to collect, store and retrieve data and relevant information, and the ability to analyze those data and information for local applications.

Task Teams

Task Teams are comprised of existing cadre in various agencies who are called on to address a specific safety problem or emphasis area under the direction of the Safety Program Leadership and Operations Manager. Different Task Teams will have different members from various agencies depending upon the emphasis area.

Process

Process refers to the steps necessary to achieve the overall roadway safety goal identified by the Safety Program Leadership. The Integrated Safety Management Process is comprised of six steps, which are:

1. Review highway safety information
2. Establish emphasis areas and goals
3. Develop objectives, strategies, and preliminary action plans to address the emphasis areas
4. Determine appropriate combination of strategies for identified emphasis areas
5. Develop detailed action plans
6. Implement the action plans and evaluate performance.

A more detailed document on safety management may be found in NCHRP Report 501: Integrated Management Process to Reduce Highway Injuries and Fatalities Statewide (PDF) which provides an overall framework for coordinating a safety management system. NCHRP Report 501 describes a detailed process that is formal, detailed, and quite thorough. The Integrated Safety Management Process is also multi-disciplinary for the development of strategies. By multidisciplinary we mean a structure where the strategies to address emphasis areas are discussed by task teams made up of members of different disciplines. This is a different structure than how agencies have traditionally worked which was single-disciplinary and multi-emphasis area, where each discipline developed strategies to address all safety problems independent of other disciplines. Figure 2 depicts the two structures for comparison. An Integrated Safety Management Process is one which follows the single-emphasis area multi-disciplinary structure which allows different agencies to work together towards the same goal.

Safety Management Systems: Current Status

There is no safety management system legislation at the national level in Canada. By comparison, the United States passed in August 2005 its transportation legislation SAFETEA-LU (http://www.fhwa.dot.gov/safetealu/) which includes requirements that states develop strategic highway safety plans which “addresses engineering, management, operation, education, enforcement, and emergency services.” This is what

is meant by a multidisciplinary approach to road safety. The Federal Highway Administration guidance document on implementing SAFETEA-LU includes the following sections:

- Leadership Support and Initiative
- Gather and Analyze Data
- Adopt a Strategic Goal
- Identify Key Emphasis Areas
- Identify Key Emphasis Area Performance Based Goals
- Identify Strategies and Countermeasures
- Determine Priorities for Implementation
- Evaluate the Plan

Emphasis Areas

In the United States, the American Association of State Highway Transportation Officials approved a national plan that included 22 emphasis areas, which are (Lifelines, http://safety.transportation.org/doc/lifelines-1.pdf Vol. 1, No. 1 March 2004):

1. Instituting graduated licensing for young drivers.
2. Ensuring drivers are fully licensed and competent.
3. Sustaining proficiency in older drivers.
4. Curbing aggressive driving.
5. Reducing impaired driving.
6. Keeping drivers alert.
7. Increasing driver safety awareness.
8. Increasing seat belt usage and improving air bag effectiveness.
9. Making walking and street crossing safer.
10. Ensuring safer bicycle travel.
11. Improving motorcycle safety and increasing motorcycle awareness.
12. Making truck travel safer.
13. Increasing safety enhancements in vehicles.
14. Reducing vehicle-train crashes.
15. Keeping vehicles on the roadway.
16. Minimizing the consequences of leaving the road.
17. Improving the design and operation of highway intersections.
18. Reducing head-on and across-median crashes.
19. Designing safer work zones.
20. Enhancing emergency medical capabilities to increase survivability.
21. Improving information and decision support systems.
22. Creating more effective processes and safety management systems

The National Cooperative Highway Research Program 500 series Reports (http://safety.transportation.org/guides.aspx) have titles which correspond to the 22 emphasis areas; The following are available at the time of writing:

Volume 1: Aggressive-Driving Crashes
Volume 2: Unlicensed Drivers and Drivers with Suspended or Revoked Licenses
Volume 3: Crashes with Trees in Hazardous Locations
Volume 4: Head-On Crashes
Volume 5: Unsignalized Intersection Crashes
Volume 6: Run-Off-Road Crashes
Volume 7: Crashes on Horizontal Curves
Volume 8: Crashes Involving Utility Poles
Volume 9: Crashes Involving Older Drivers
Volume 10: Crashes Involving Pedestrians
Volume 11: Seat Belt Use
Volume 12: Crashes at Signalized Intersections
Volume 13: Crashes Involving Heavy Trucks
Volume 14: Drowsy and Distracted Drivers
Volume 15: Rural Emergency Medical Services
Volume 16: Alcohol-Related Crashes
Volume 17: Work Zone Crashes

Canada's Road Safety Vision 2010 sets out Canada's national road safety quantitative goals for the year 2010. In Canada's Road Safety Vision 2010, emphasis areas are referred to as targets or sub-targets. The targets in Road Safety Vision 2010 are:

1. Unrestrained fatalities/injuries
2. Rural roadways fatalities/injuries
3. Impaired driving fatalities/injuries
4. Commercial vehicle fatalities/injuries
5. Young driver fatalities/injuries
6. Speed & intersection fatalities/injuries
7. Vulnerable user fatalities/injuries
8. High risk driver identification (updated as of December 2005)

The key to choosing an appropriate categorization of emphasis areas is to separate the concept of an emphasis area from the concept of a strategy. Eliminating shoulder drop-offs is a strategy to address roadway departure emphasis area. A strategy is a treatment, device, application, practice, or action to improve safety within an emphasis area such as installing rumble strips to reduce roadway departure collisions, imposing sanctions against repeat offenders to reduce impaired driving, or holding child and booster seat training sessions at community centers to increase restraint usage.

Data Analysis for Selecting Emphasis Areas for a Jurisdiction

The data analysis side of the Integrated Safety Management Process can be summarized by one word: "prioritization". Any jurisdiction or agency only has so many resources available, so we want to apply those resources where they will get the "most bang for the buck". The formal process in the Integrated Safety Management Process examines all the possibilities and chooses those which return the highest benefit-cost ratios. One can be

said to be following an Integrated Safety Management Process if the following elements are prioritized:

- The membership of the leadership group. A safety program leadership group that is too large will be too difficult to manage and will take too long to make decisions. Not everyone who is involved in safety should be part of the safety program leadership. Those agencies which do not fit within the safety program leadership may be more appropriate for the emphasis area task teams.
- The emphasis areas; about 4 to 8 different emphasis areas is a reasonable number. A strategic plan which lists 22 different emphasis areas is not prioritized. For most jurisdictions it is not possible to execute an action plan which includes schedules and budgets for so many different emphasis areas because there aren't enough resources to go around.
- The strategies. The NCHRP Report 500 series are a good source of strategies for different emphasis areas, but again it is not feasible or cost effective to implement all the strategies listed. Only those strategies that are appropriate for the jurisdiction should be selected for implementation.
- The time frames, locations, and targets of the strategies being implemented. An enforcement strategy targeting aggressive drivers should be implemented during those peak times when the number of aggressive driving violations is highest. Intersection engineering treatments should be implemented at locations with the greatest potential for safety improvement. Education and marketing campaigns aimed at impaired drivers should be timed together at peak seasons when drinking and driving is highest such as the winter holidays (Christmas, New Years), or May (graduation ceremonies, prom).

The formal process for selecting emphasis areas requires data analysis which examines the number of collisions and their severity for each emphasis area and compares the numbers. The short cut presented in this paper is to examine what emphasis areas have been selected by other jurisdictions and then to do the same.

We reviewed the strategic plans of 19 States (Alabama, Connecticut, Delaware, Florida, Illinois, Iowa, Kentucky, Louisiana, Maine, Maryland, Michigan, Minnesota, Missouri, Nevada, New Mexico, New York, Pennsylvania, and South Carolina). Six of the strategic plans did not follow the ISMP concept of prioritization and they include every emphasis area covered by the NCHRP 500 series guides. Nevertheless, the review reveals that every plan includes the following three emphasis areas:

1) Restraint usage
2) Impaired driving
3) Aggressive driving

Restraint usage should include adult safety belts and child seats. Impaired driving should include drowsing driving. Aggressive driving may be defined as collisions which involve drivers that have been cited for things such as speeding, improper passing, following too closely, and aggressive driving. Given that all three of these emphasis areas may be found in every U.S. strategic plan reviewed, and they appear in Canada Vision 2010, it would appear to be a reasonable assumption that they should be emphasis areas for every

jurisdiction in Canada. Those few jurisdictions that do not have restraint usage, impaired driving, or aggressive driving as emphasis areas are exceptions which prove the rule. Notice that these three emphasis areas call for a multidisciplinary team approach to address beyond traditional engineering treatments.

The fourth emphasis area can be selected by first asking if the jurisdictional roads include more rural roads and highways or more urban environments. For a jurisdiction with more rural highways, the fourth emphasis area selected should be roadway departures (including head-on and median barrier collisions. Otherwise for a more urban environment the fourth emphasis area selected should be vulnerable users (pedestrians, bicyclists).

How does one select additional emphasis areas beyond the first four (or five for large jurisdictions that include both rural and urban environments)? Again, a formal process such as the ISMP would dictate that an analysis of collision data should be conducted to select any additional emphasis areas. However, a less scientific but more practical way would be to simply look at the membership of the safety leadership group. Do the members include agencies that have significant interests in one particular emphasis areas? Are there any emphasis areas that have strong leadership and have shown success over the years? An emphasis area with strong agency involvement or interest must be included. If the safety leadership includes any legislative members, are there any political issues that should be considered? In an ideal situation any additional emphasis areas would be selected on the basis of data driven decisions. However, additional emphasis areas beyond the first four may be selected on the basis of political, social, or practical considerations. These considerations are usually well known at the management level of an agency.

This simplified process of selecting emphasis areas, as diagramed in Figure 3, can be accomplished in a matter of minutes compared to formal data analysis which requires hours to days worth of database queries and analysis. This process has been developed based upon an analysis of other jurisdictions and Canada's Road Safety Vision 2010. Our experience indicates that a formal process to select emphasis areas will lead to a nearly identical priority list of emphasis areas as will be obtained using the simplified process. In addition, we have also found one additional emphasis area, collisions with animals, to have particular importance with highly rural jurisdictions.

Network Screening: High Proportion

High proportion testing is an appropriate methodology for network screening when traffic volume data are not available. High proportion testing may be applied wherever collision history and roadway inventory information are available. This screening method is also simple enough to be applied using only a spreadsheet. It can also be applied to emphasis area collisions. The key is to select collisions on the basis of which emphasis area the collision falls under. This methodology has been successfully applied for a state department of transportation in the U.S. for four different emphasis areas (roadway departure, impaired driving, aggressive driving, and restraint usage). The emphasis area

specific screening results can then be shared with each emphasis area task team so that they can identify which locations are most over-represented in terms of an emphasis area crash type and are in need of treatments.

Generally, for each location (highway segment or intersection as the case may be), the probability that the proportion of a specific collision type is higher than the average proportion in that functional class is computed based on the binomial test. If this probability is less than a certain significance level (i.e., 5%), the location is identified and the number of specific collisions out of the total number of collisions at that location is reported. For example, a value of 8/10 would mean that there were eight collisions of that collision type out of a total of 10 collisions at that location, and that the proportion is substantially greater than what one would expect to occur strictly by chance. This screening method identifies highway segments that have a high proportion of a target collision (i.e. run-off-road, impaired) in relation to all collisions within a functional class, for all collision severities combined. This relatively new methodology, based on the binomial test, has been previously outlined in work by Kononov and Allery (2)

The High Proportion test as identified by Mollett {Mollett, 2004 263 /id} is not as reliable as the Bayesian test proposed by Hedecker and Wu (4), but we have found it to be sufficient for emphasis areas with base proportions of collisions greater than 10%.

High Proportion Test

If a collision occurs, its probability to be of target collision a is P_a. P_a is calculated based upon the total observed frequency of target collisions n_a divided by the total number of collisions N within a functional class. For example, 35 roadway departure collisions out of 100 total collisions gives $P_a = 0.35$.

N is equal to the total number of collisions. The probability P that (given the number of collisions of target type a,) n_a collisions of target type a occur out of a total of N collisions, is given by the binomial distribution:

$$P((N_a=n_a), N, P_a) = \left(\frac{N}{n_a}\right) P_a^{n_a} (1-P_a)^{N-n_a}$$

where

P_a = probability that a collision is of target collision a $\left(\frac{N}{n_a}\right) = \frac{N!}{(N-n_a)!n_a!}$

The probability that n_a or more collisions will be observed out of N total collisions can be computed as:

$$P(N_a \geq n_a) = 1 - \sum_{0}^{n_a-1} \frac{N!}{(N-i)!i!} P_a^{\,i} (1-P_a)^{N-i}$$

By setting some critical level of $P(N_a \geq n_a)$, segments which are experiencing an above normal proportion of a target collision can be identified for a detailed safety study

In order to produce meaningful results, the base probability of target collision (P_a) needs to be higher than 10%.

Example 1:

Consider a road segment with the following 5-year collision history:
N = 30 collisions in total
n_a = 15 run-off-road collisions

If, for similar road segments (road segments from the same functional class), run-off-road collisions are expected to be 35% of total collisions ($P_a = 0.35$), in order to know if 15 run-off-road collisions are overrepresented out of a total of 30 collisions at this site, the following calculation takes place:

$$P(N_a \geq 15) = 1 - \sum_{0}^{15-1} \frac{30!}{(30-i)!i!} 0.35^i (1-0.35)^{30-i}$$
$$= 0.03$$

Thus, there is only a 3% chance that a road segment could experience 15 run-off-road collisions or more out of 30 run-off road collisions given a base probability of 35% right-angle collisions. If one has cut-off criteria of 5%, this road segment would be considered to be over-represented for run-off-road collisions because the probability of 15 out of 30 collisions occurring is less than 5%. Therefore, one might conclude then that run-off-road collisions are overrepresented at this site, and therefore a detailed safety investigation is warranted.

Example 2:

The base probability of target collision (P_a) needs to be higher than 10%
Consider a rare contributing circumstance that occurs less than 0.05% of the time such as "rail collision". If 1 rail collision occurs on a road segment over a period of 5 years out of a total of 10 collisions, then the probability of 1 collision occurring out of 10 is significantly higher than one would expect for a collision type which occurs in general only 1 time out of 100. The actual probability is computed as less than 5% as follows:

$$P(N_a \geq 1) = 1 - \sum_{0}^{0} \frac{10!}{(10-i)!i!} 0.005^i (1-0.005)^{10-i}$$
$$= 0.049$$

Even though a segment may not have a railway collision problem, the single occurrence of a low probability collision is enough to result in a false positive, a result which appears

to be an overrepresentation of a collision type when, in fact, no overrepresentation exists. P_a should be higher than 10%, in order to produce meaningful results.

Conclusions

This paper has presented a multidisciplinary approach to road safety that focuses upon emphasis areas, areas of safety concern. While a proper data analysis is always recommended, an alternative simplified emphasis areas selection guide has been presented based upon the strategic plans of other jurisdictions and taking into account political, social, and practical constraints. In addition, the paper contains an overview of a test for overrepresentation that has been successfully used to determine priority locations for applying emphasis area specific strategies. Thus, by conducting network screening by emphasis area related collisions, the paper has presented how network screening fits within a safety management system.

References

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Figures

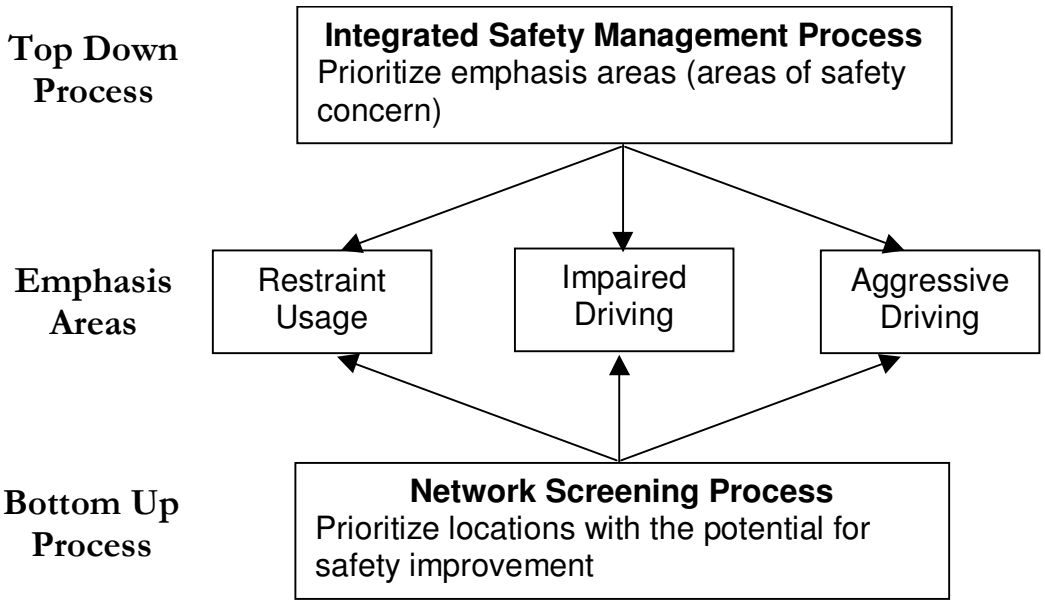

Figure 1. Top down and bottom up processes for selecting emphasis areas

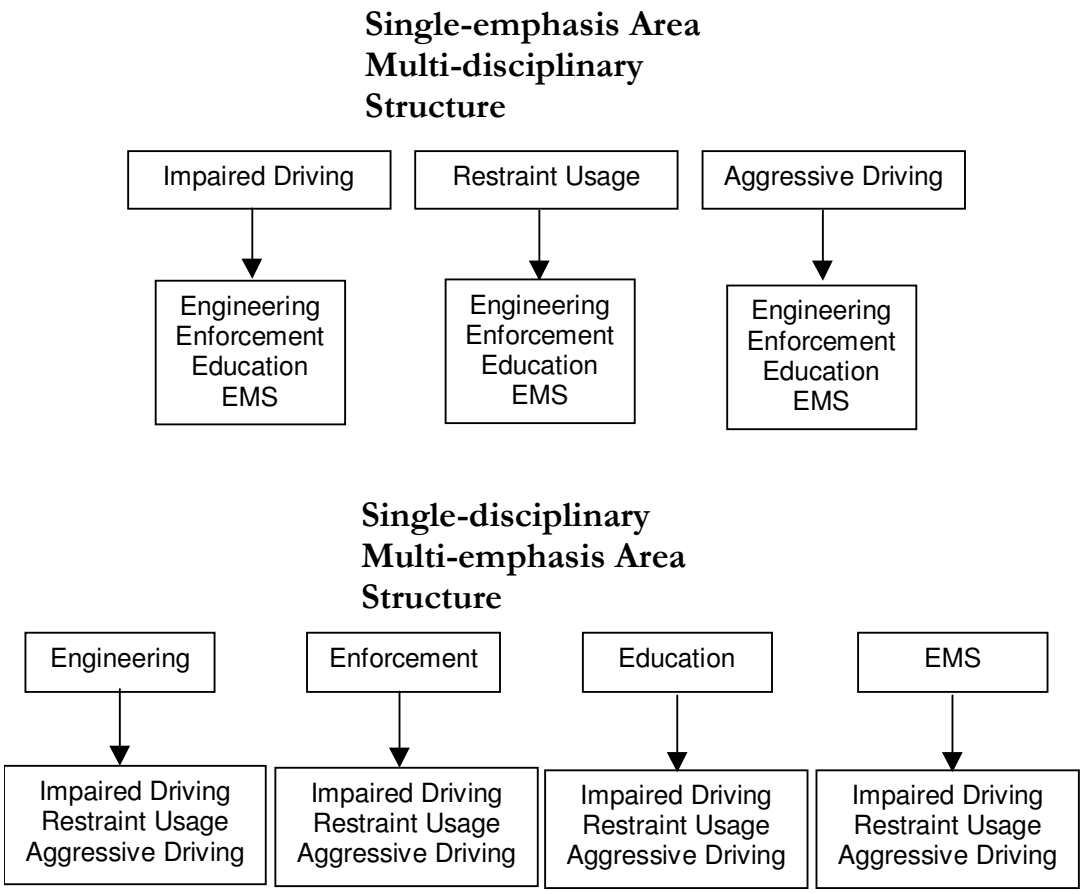

Figure 2. Single-disciplinary vs. multi-disciplinary structures

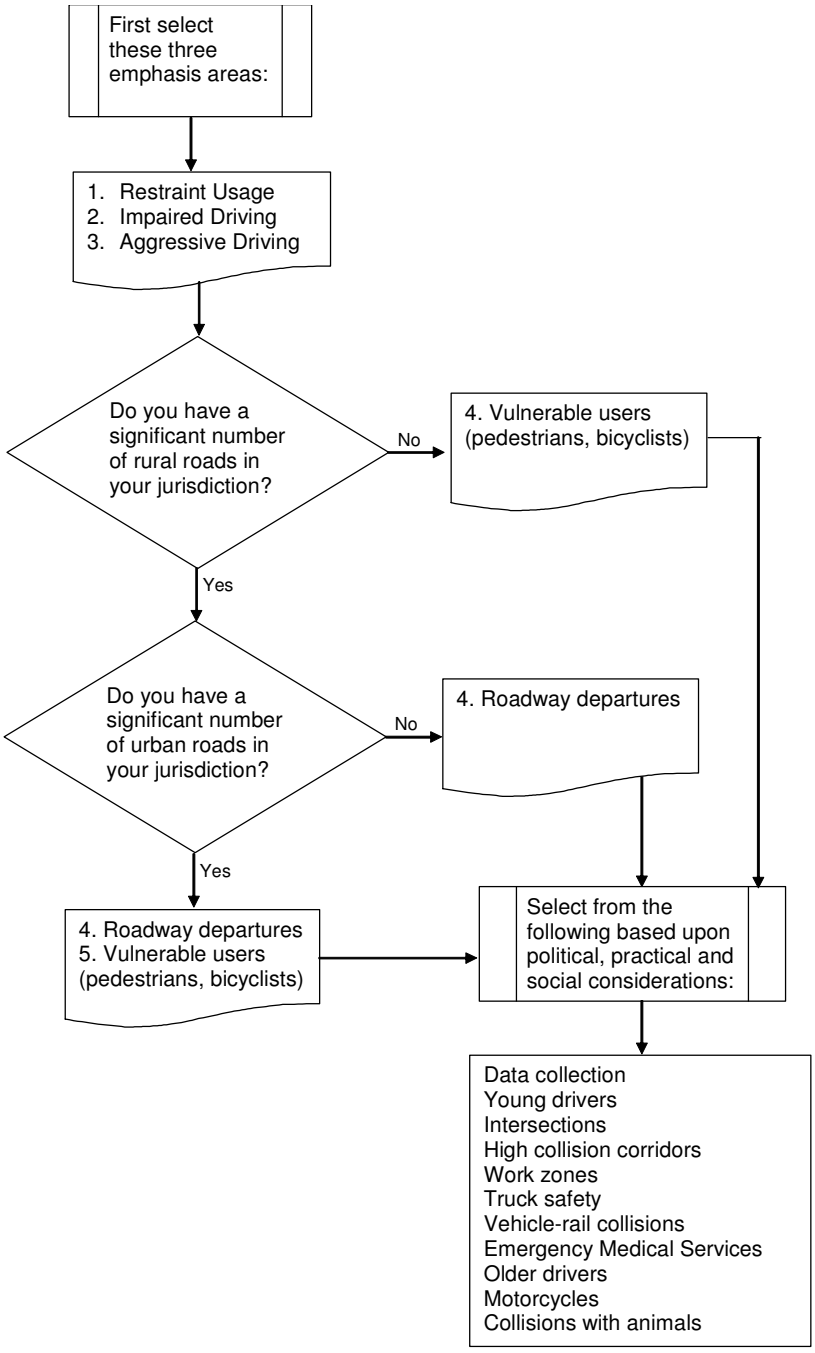

Figure 3. Simplified emphasis area selection decision guide