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Summary:

State-of-the-art approaches to road accident black spot management and safety analysis of road networks

Aim of the report and main research problems

This report presents state-of-the-art approaches to road accident black spot management and safety analysis of road networks. The term state-of-the-art approaches refers to the best approaches from a theoretical point of view, which are not necessarily identical to any approaches currently used. The report describes two activities that are essential elements of any system for safety management of roads:

1. Identification, analysis and treatment of road accident black spots (black spot management).
2. Safety analysis of road networks.

The report is part of the RIPCORD-ISEREST project funded by the European Commission. The main objective of the report is to describe state-of-the-art approaches to black spot management and safety analysis of road networks. The state-of-the-art approaches are compared to approaches that are currently used. Based on this comparison, guidelines for best practice will be developed in a subsequent report. The main research problems studied in this report are:

1. What is the state-of-the-art approach (i.e. theoretically best approach) to road accident black spot management?
2. Which approaches to road accident black spot management are currently used in European countries?
3. What is the state-of-the-art approach to safety analysis of road networks (network safety management)?
4. Which approaches to network safety management are currently used in different countries?

Elements of the state-of-the-art approach

The report concludes that a systematic use of the empirical Bayes method for road safety estimation represents the current state-of-the-art with respect to both black spot management and network safety management. The empirical Bayes approach has so far not been widely applied in Europe, but is widely used in North America.

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The essential elements of an emerging state-of-the-art are as follows:

1. Black spots should be identified in terms of the expected number of accidents, not the recorded number of accidents.
2. Black spots should be identified by reference to a clearly defined population of sites, whose members can in principle be enumerated.
3. Use of a sliding window approach to identifying black spots is discouraged. This approach artificially inflates variation in accident counts.
4. To estimate the expected number of accidents, multivariate accident prediction models should be developed.
5. The best estimate of the expected number of accidents for a single site is obtained by combining the recorded number of accidents with the model estimate for that site. This should be done by applying the empirical Bayes method.
6. The performance of alternative critical values for the expected number of accidents qualifying a site as black spot should be investigated in terms of sensitivity and specificity. An optimal criterion should be chosen.
7. The traditional criterion for a true black spot, which is that there is a dominant pattern of accidents, has not been validated. Analysis of accidents at black spots is best viewed as a means of developing hypotheses regarding potentially contributing factors to the accidents.
8. Analysis of black spots should recognise the possibility that an apparent pattern may arise as a result of chance alone. Binomial tests should be applied to determine the probability that a certain number of accidents of a certain type is the result of chance only.
9. Analysis of black spots should employ a blinded design and rely on a comparison of the black spot to a safe location. The task of analysts is to identify risk factors for accidents. Analysts should not known which site is the black spot and which site is the safe one.
10. Evaluation of the effects of black spot treatment should employ the empirical Bayes before-and-after design.

A state-of-the-art approach to safety analysis of road networks should contain all these elements. In addition, a state-of-the-art approach to safety analysis of road networks should include a routine for merging adjacent sections for the purpose of accident analysis. The profiles and peaks algorithm is suitable for this purpose.

The empirical Bayes approach to road safety estimation

The empirical Bayes approach to road safety estimation has been developed by Ezra Hauer. The approach makes it possible to provide unbiased estimates of the long-term expected number of accidents for individual elements of the road system, such as a specific junction, a specific curve or a specific road section. This represents major progress in road safety estimation and permits an elimination of the bias attributable to random fluctuations in the recorded number of accidents (bias attributable to regression-to-the-mean).

By applying the empirical Bayes approach systematically, it is possible to identify hazardous road locations that have an abnormally high expected number of accidents, not just a recorded number of accidents that happened to be abnormally high due to randomness. This implies that the identification of hazardous road locations can be made substantially more accurate than before. The report presents studies comparing different criteria for identifying hazardous road locations. The empirical Bayes technique performs better than any other method according to commonly accepted epidemiological criteria of diagnostic accuracy.

There are several variants of the empirical Bayes approach. The most sophisticated version estimates the expected number of accidents by combining knowledge extracted from two sources:

1. A multivariate accident prediction model, which describes the normal level of safety and the effects of variables influencing it. The most common form of accident prediction model is a negative binomial regression model.
2. The recorded number of accidents for a specific site during the same period as that used in fitting the accident prediction model.

These two sources of knowledge are combined linearly. A weight is assigned to the normal number of accidents and a complementary weight (i.e., the weights sum to 1) is assigned to the recorded number of accidents. The better the accident prediction model (in terms of the share of systematic variation in the number of accidents explained by it), the greater is the weight attached to its predictions.

Developing good accident prediction models is difficult. The report therefore includes a review of methodological problems involved in developing and fitting accident prediction models.

Black spot management

Black spot management has a long tradition in traffic engineering and has been held in high esteem. The report describes the current approaches to black spot management in Austria, Denmark, Flanders (Belgium), Germany, Hungary, Norway, Portugal and Switzerland. The review shows that none of these countries have fully implemented a state-of-the-art approach to black spot management today. Portugal is the only country in which the empirical Bayes approach is partly implemented. There is, in general, a considerable gap between current practice and the state-of-the-art approach.

The report shows how to identify hazardous road locations by means of the empirical Bayes approach. It is moreover argued that current techniques for accident analysis need to be developed, as these techniques are not currently able to discriminate between false positives and true positives with sufficient precision.

Accident prediction models: a methodological review

Accident prediction models are important both with respect to black spot management and with respect to network safety management. The report discusses a number of methodological problems associated with the development and fitting of accident prediction models. The discussion is concluded by a list of criteria that can be used to evaluate the quality of accident prediction models.

Network safety management

The main objective of network safety management is partly the same as that of black spot management: to identify those sites that are in greatest need of road safety treatment. There are, however, two important differences between black spot management and network safety management:

1. In network safety management, an important objective is to identify longer sections of road that have safety problems. A black spot, on the other hand, is usually a very local point on the road system, like a junction.
2. In network safety management, account is taken of accident severity and an attempt is made to identify road sections where fatal and serious injury accidents are overrepresented. In black spot management, the number of accidents at each black spot is usually too low to permit a meaningful consideration of accident severity.

Systems for network safety management in Germany, Norway and the United States are described in the report. The systems implemented in Norway and the United States are based on the empirical Bayes approach. In the United States, an algorithm designed to identify longer road sections with safety problems, profiles-and-peaks, has been implemented. If longer road sections are used, the number of accidents serving as basis for analysis is increased.