ACCIDENT RATES MODELLING AND ROAD SAFETY EVALUATION

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ABSTRACT

Traffic safety has increased in importance in recent years and has thereby placed greater responsibility on the highway and traffic engineer to estimate the safety consequences of new road construction and traffic management schemes. In order to assess the effect of engineering measures on accident rates it is necessary to estimate the expected accident rates at the study site prior the application of the engineering measures and the accident rate occurring after the treatment. This paper presents a new methodology for accident rates modelling to assess the effectiveness of engineering treatment on accidents occurrence and introduces measures to evaluate road safety, as well as presents traffic calming measures to reduce accidents occurrence.

Keywords: Transportation Management and Control, Road safety, Accident Rate, Accident Modelling, GIS, Cost Benefit Analysis, Cost-Effectiveness, Traffic Calming Measures.

INTRODUCTION

In collisions between cars and pedestrians, the pedestrians' chances of being killed rise dramatically with an increase in the speed of the car [9]. The probability of a pedestrian fatality is 5% at 30 km/h, rising to 37% at 50 km/h and to 83% at 70 km/h. This is clearly crucial in urban areas with speed limits at 50 to 60 km/h. A reduction in motor traffic speed to 30 km/h would not only reduce the levels of pedestrian injuries sustained in collisions, but also give both parties a better chance of avoiding the collision in the first place.

Road safety is an important issue. It involves large numbers of people, vehicles, and road sections, and as such is a complex issue to understand and manage. Because of the size and scope of the problem, the databases required are generally large, and are required to be accessible to a wide variety of users.

Road safety engineering needs basic facts including accidents, road network and traffic data. Using such data, it is possible to investigate the principles relating to the occurrence of various types of accidents, and to develop standards which incorporate safety measures into the design of roads and the town planning. Also, it will help to identify and treat those components of the transportation system which result in the most effective improvements in road safety.

The objectives of this paper is to develop a new method for accident rates modelling to assess the effectiveness of engineering treatment in accident occurrence, as well as to introduce new measures to evaluate road safety, and to present traffic calming measures to reduce accidents occurrence.

FACTORS TO BE CONSIDERED BY ACCIDENT RATES MODELLING

The main purpose of accident rates modelling (pedestrian or traffic) is to develop useful relationships between road accidents and a set of town planning, traffic, and road geometric variables. The main step of accident modelling may be the establishment of statistical correlation matrices among the different potential variables. This step enables the selection of independent variables that are highly correlated with the dependent variables.

The main factors which can be considered by accident modelling are:
* Town planning factors,
* Road geometry factors,

* Traffic factors, and
* Accident data

Town planning factors are divided into two groups. The first group includes population, number of housing and commercial units, level of employment, number of schools and number of students in each school, type of the urban network and intersections. The second group of factors belongs to accident rates modelling in rural roads and includes the distance from the town to the road, the town frontage distance (length of road adjacent to the town), distance to the nearest city, the number and type of accesses per kilometer of the frontage distance, and the distribution of the town around the road.

Road factors that may be considered by accident modelling include the number of horizontal and vertical curves within the study area. Only those vertical curves with insufficient passing-sight distance may be considered. Pavement, number and width of lanes, shoulder widths, and the number and type of traffic control devices and speed limits can be also considered.

Traffic data that may be considered by accident modelling include the average daily traffic volume (ADT) and traffic composition, and through-traffic speed.

Accident rate and accident locations are important data for accident modelling.

A NEW METHOD FOR ACCIDENT RATE MODELLING

The assessment of the effectiveness of engineering measures in reducing accident rates at a site requires a comparison of the observed accident rate at the site in the period after treatment with the expected accident rate had no treatment taken place.

Accident rates used for road safety comparisons are usually expressed in number of accidents per vehicle kilometers driven. This implies that traffic accidents are proportional to the volume of traffic. A great deal of research has been carried out in this respect and shows the relation of road accidents to traffic volumes as follows:

$$R = (A * 10^6)/(365*q*T*L) \qquad (1)$$

where:

R: is the accident rate (accidents/ 10^6 vehicle kilometer per year)
A: is the number of observed accidents
q: is the rate of traffic flow (veh./day)
T: is the time period of the observed accidents in years
L: is the road length in km

By introducing levels of service (LOS) instead of traffic flows, an accident analysis will indirectly consider the effect of the roadways factor and the traffic factors. Frantzeskakis [7] proved that accident rates are closely related to the level of service of road network under which each accident takes place. This means that the accident rate R for a LOS n can be defined as follows:

$$R_n = (A_n * 10^6)/(365*T*L*(v/c)_n) \qquad (2)$$

Considering the number of hours per day that an examined road section operates under LOS n, model (2) can be expressed as follows:

$$R_n = (A_n * 10^6)/(365*T*L*F_n*(v/c)_n) \qquad (3)$$

where:

R_n: is the observed accident rate (accidents/ 10^6 kilometer.hour under LOS n per year)
A_n: is the number of observed accidents occurring under LOS n
F_n: is the number of hours per day that the examined road section operates under LOS n
$(v/c)_n$: is the average ratio of the volume to capacity for the LOS n

The basic structure of the proposed method for accident rates modelling consists of three steps.

The first step involves the preparation of a list of the observed accidents, occurring under LOS n, at the study site before (A_{nb}) and after (A_{na}) the introducing of a certain engineering measure.

The second step involves the determination of the observed accident rate before and after the treatment per 10^6 kilometer (R_{nb} and R_{na}) and the corresponding LOS n. The LOS can be determined according to the Highway Capacity Manual Method [11], and the R_n can be calculated according to model (3):

$$R_{nb} = (A_{nb} * 10^6)/(365*T*L*F_n*(v/c)_n) \quad (4)$$

$$R_{na} = (A_{na} * 10^6)/(365*T*L*F_n*(v/c)_n) \quad (5)$$

where:
a,b: is denoted for "after" and "before" the treatment.

The third step involves the determination of the expected accident rate before the treatment. Depending on the Empirical Bayes method [19], the expected accident rate before the treatment can be described by the following model:

if m_n is the expected accident rate before the treatment at a site with LOS n and R_{nb} is the accident rate occurring under LOS n before the treatment, the mean value of R_{nb} of the examined road is R_{nb}' and the variance is S^2, then:

$$m_n = a * R_{nb}' + (1 - a) * R_{nb} \quad (6)$$

$$a = \{1 + (S^2 - R_{nb}')/ R_{nb}' \}^{-1} \quad (7)$$

$$R_{nb}' = \sum_{1}^{N} R_{nb}/m \quad (8)$$

$$S^2 = (1/(m-1)) * \sum_{1}^{N} (R_{nb}-R_{nb}')^2 \quad (9)$$

where:
N: is the number of level of service (A to F)

The effect of engineering measures on accident rates at a site, E, can be expressed as:

$$E = R_{na} / m_n \quad (10)$$

where:
R_{na}: is the observed accident rate after treatment,
m_n: is the expected accident rate.

Thus, if engineering measures have had no effect on accidents, E = 1; if treatment has reduced accidents, E<1; and if treatment has increased accidents, E>1. The percentage change in accident rates following treatment, E%, is given by:

$$E\% = (R_{na} - m_n)* 100\% / m_n \quad (11)$$

APPLICATION

Assuming a road length of 18 km with traffic characteristics and observed accidents per 2 years as in Table (1). Applying model 4 and 5 to get R_{na} and R_{nb} (the values in the last two columns of table 1). The accident rate before treatment per 10^6 kilometer.hour under LOS A (v/c=o.173) equal to 3707, and after treatment equal to 3244.

Applying models 6 to 11:
R_{nb}' = 1152, S^2 = 1 697 191
a = $5.892 * 10^{-7}$
m_n = 3706
E = 0.875, E% = 12.5

This means that a reduction of accident rates of 12.5% can be achieved by a certain engineering measure.

MEASURES TO EVALUATE ROAD SAFETY

Generation of Accident Analysis System With Integrated Gis

GIS (Geographic Information System) is commonly described as a collection of hardwares, softwares and geographic data that together allows the analysis and reporting of geographic information.

The fundamental difference of a GIS from any other information systems is that it has the knowledge of how events and features are geographically located.

The advent of GIS can offers a new avenue for road safety enforces to study accidents with analytical tools that are powerful and easy to use. A PC-oriented database for road safety improvements and management can be of great benefit.

The GIS can be applied to road safety analysis and management. The system includes establishment of data files. This database includes road network database, a comprehensive land use database, traffic flow database, accident database, and a traffic management database. In this issue, it is essential to define the aims and the purposes of the system to be established. Weather the system is designed for research and analysis, or also for safety management and interaction with other Transportation functions. It is important that the system design be open and able to be expanded and upgraded. Accurate statistical data are vital for identifying the characteristics of traffic accidents and for preparing traffic safety plan.

Table 1. Accident Rates Calculations as an Example.

LOS	$(v/c)_n$	A_{nb}	A_{na}	F_{nb}	F_{na}	R_{nb}	R_{na}
A	0.173	59	50	7	8	3707	3244
B	0.407	41	37	6	6	1277	1153
C	0.639	25	23	5	4	595	744
D	0.838	15	13	3	3	454	393
E	1.028	5	3	2	2	185	111
F	1.206	11	8	1	1	694	504

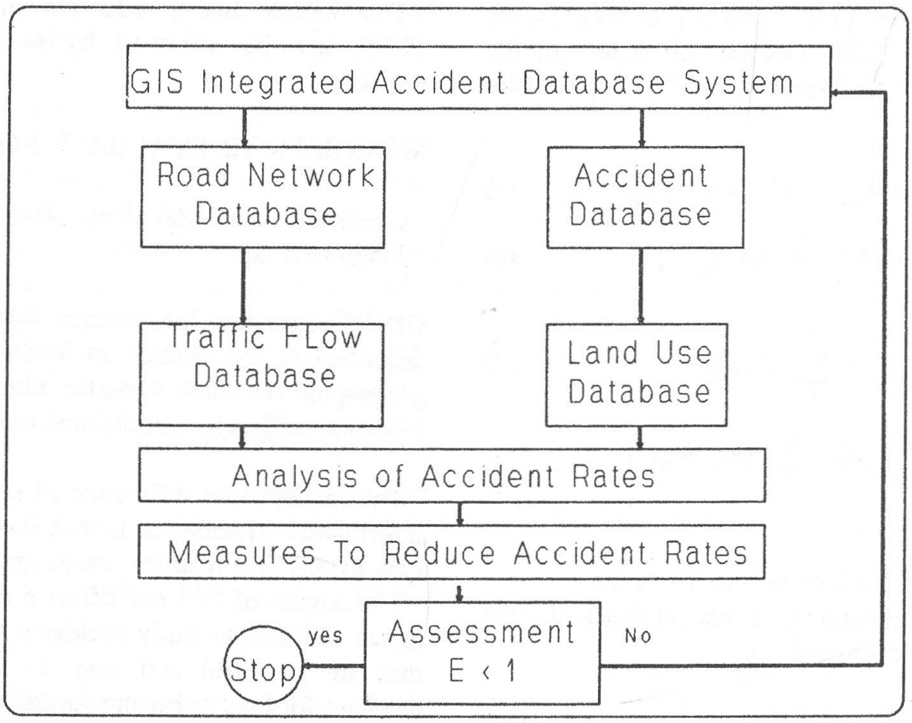

Figure 1. The main components of a proposed GIS integrated accident data base system.

Figure (1) shows the main components of a proposed GIS integrated accident data base system to analyze and evaluate road safety systems.

The integration of the accident database into GIS may help the display of accident data in many ways. Various categories, such as spatial searches include finding events within a specified radius from a certain location, determination of areas that are prone to accidents, determination of accidents within a selected area showing the distribution of the types of accidents, the ratio of the number of serious or fatal accidents to the total of injury accidents, interactive viewing of danger spots, all these can be displayed on maps or one map. These displays are an enhancement to develop safety programs and strengthen the decision-making capability of safety administrators. The GIS integrated accidents database system enables traffic engineers and managers to understand the overall accident situation in their area or at a particular location, and how it is changing at frequent intervals. It will also enable traffic engineers to determine traffic operational solutions and to establish priorities for improvements on a regular basis.

The geographic accident database using GIS may be structured in such a way that the total number of accident rates on a street segment, intersection, a whole street length or an area, can be determined. Accidents of a particular type can be analyzed and viewed in relation to the location of an activity center or in relation to any selected road feature (location of schools, etc.).

ACCIDENTS SAVED BENEFITS

The following two approaches may be considered for economic analysis of accidents saved:

* Benefit/Cost Analysis (BCA), and
* Cost-Effectiveness Analysis (C/E)

Benefit-Cost Analysis can be used to consider weather an engineering measure should be done at all/or its relative position in regard to other measures, or to assess the value of a treatment.

Basically the initial costs and the costs of continuing operation throughout the "life" of the treatment (or measure) may be compared with the estimates of the benefits (and losses) due to the operation of the measure over the same life span.

To use the BCA as a method to evaluate road safety, it is required to know the service life of the treatment, in addition the following are needed:

* the initial capital costs;
* the yearly operating and maintenance costs;
* the estimated change in the frequency of the particular accident type affected by the treatment;
* the respective costs per accident for the accident type; and
* the costs of increase / decreases in traffic delays and any other relevant parameters.

The benefit/cost (B/C) ratio can be calculated by the following model, which based on annual benefits to costs:

$$B/C = (NAS * CPA) / (I + K)$$

where:

NAS: yearly number of accidents saved due to introducing an engineering measure
CPA: cost per accident
I : yearly capital costs of a treatment
K : yearly operating and maintenance costs of a treatment

The Cost-Effectiveness Analysis (C/E) indicates the cost of saving one accident. The following equation based on an annual benefits to costs, illustrates the input variables used in calculation of C/E:

$$C/E = [I + K] / NAS$$

MEASURES TO REDUCE ACCIDENT RATES

Blumenthal [6] mentioned that the event of an accident is a problem of faulty coordination between the level of performance of the driver and the performance demand of the road network.

Figure 2 presents schematically the performance level of the driver and the performance demand of the road network as a function of time. The demand of the network vary according to various levels of design, types of roadway, rates of traffic flow, and LOS. When the performance level of the driver is not compatible with the performance demand of the network, an accident occurs.

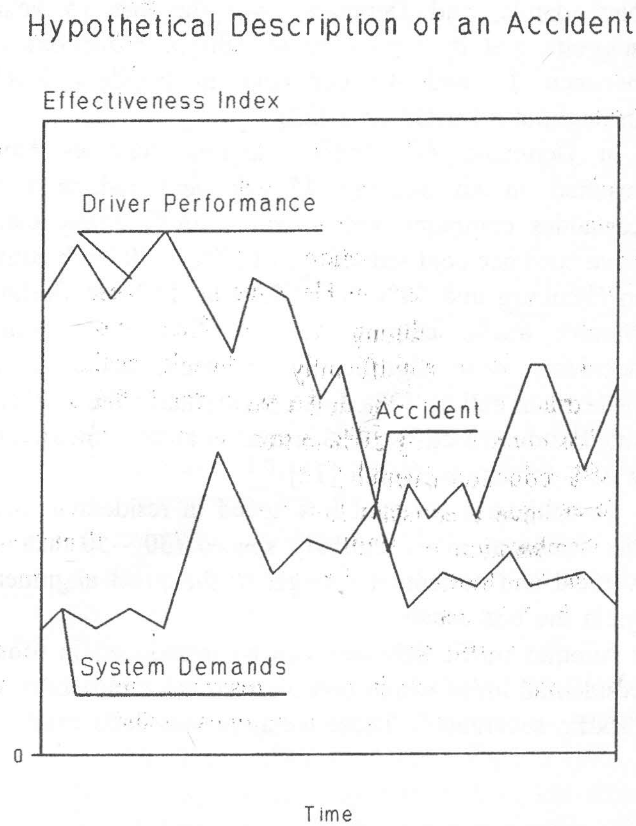

Figure 2: Hypothetical Description of an Accident

The engineering improvements in the road infrastructure is reflected in an equivalent lowering of the performance demand. As a result, the gap grows between the performance level of the driver and the performance level of the demand of the network, and the probability of road accidents lessens. It means that engineering measures in the road are designed to simplify the problems faced by driver and to reduce risk that the performance level of the driver will be less than the level required to meet the demand of the network.

The road network can be improved at various levels. On one hand, it is possible to modify the road network, increasing the interchanges, bypasses, etc. On the other hand, a lower level of improvements may be made, such as painting, and increasing the sight distance.

Traffic calming can be seen as a way of reducing vehicle speeds and respectively accident rates. Road humps and introduction of 30 km/h zones particularly in residential area are two traffic calming measures, which can be used to reduce both the number and severity of accidents. Experience in Germany, the Netherlands, and Denmark over the last 15 years suggests that it is possible to achieve reductions of between 15 and 40 per cent in accident levels throughout a treated area [22].

In Denmark, 600 traffic calming schemes have resulted in an average 45 per cent reduction in casualties compared with controls. In Germany there have been accident reductions of 27% in 30 km/h zones in Hamburg and 44% in Heidelberg. In West Berlin's Moabit traffic calming scheme fatal and serious accidents were significantly reduced; accidents to pedestrians fell by 43%. In the Netherlands the accident rate has decreased by 50% in treated areas compared to a 20% reduction overall [13].

To achieve a constant low speed in residential area, the combination of regularly spaced (30 - 50 meters) vertical and horizontal changes to the street alignment yield the best result.

Another traffic schemes can be introduced in urban residential areas which involve restrictive measures, or "traffic severance". These techniques include road closures, turning bans, and one-way streets. These schemes can lead to significant accident reductions, but they can lead to a transfer of accidents into adjacent areas.

Finally, multidirectional approaches should be considered for the overall reduction of traffic accidents and to improve the level of performance of the driver. Roadway safety management system and schemes, strictly enforcing traffic rules and laws, strictly annual car inspections, traffic safety education and licensing programs, these all can be recommended to reduce accidents severity and frequency.

CONCLUSIONS

This Paper is directed toward understanding the accident rates analysis and modelling. Different factors that affect accident rates modelling such as town planning, road geometry, traffic factors, and accident data are analyzed. A new methodology for accident rates modelling to assess the effectiveness of engineering treatment on accident occurrence has been derived. It is believed that the methodology described in this paper is both generalizable and practical. It can provide a quantitative basis for decision making regarding introducing of traffic engineering measures to reduce accident occurrence.

A GIS integrated accident data base system to evaluate and analyses of road safety is proposed. It is important that system design be open and able to be expanded. Data collection and its accuracy is a critical element for identifying the characteristics of traffic accidents and for preparing traffic safety plan. The system should be amenable to upgrading.

The economic analysis of accident saved as a method to evaluate traffic schemes with respect to accident rates is also introduced.

Finally, multidirectional approaches should be considered for the overall reduction of traffic accidents. Traffic calming measures, introducing the 30 km/h zones, roadway safety management system and schemes, strictly enforcing traffic rules and laws, strictly annual car inspections, traffic safety education and licensing programs, these all can be recommended to reduce accidents severity and frequency.

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