STUDY AND COMPARATIVE ANALYSIS OF THE MODELS FOR TRAFFIC SAFETY PREDICTION

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Abstract: *The need of development and implementation of effective measures to increase the level of traffic safety is of utmost importance when it comes to road transport. Numerous studies on factors affecting road safety are the core of transport approaches and models made to reduce the occurrence of accidents. The purpose of this article is to make a comprehensive study of the models for analysis of the traffic conditions and their impact on traffic safety and to define the fundamental ones for implementation in Bulgarian conditions.*

Keywords: TRAFFIC ACCIDENT, TRANSPORT, TRAFFIC SAFETY, PREDICTION MODELS, ROAD TRANSPORT SAFETY, APPROACHES, VEHICLE

1. Introduction

Reducing the number of road accidents and their consequences can be sought in the amendment of factors, which determine the accidents rate, such as behavior of road users, the level of conflict of road infrastructure and its active and passive safety.

The purpose of this article is to explore accident prediction models in order to be considered working methods for predicting traffic accidents in Bulgaria and to reduce their number. By examining the current state of the problem, the interrelationships with other types of accidents and the overall situation on the road, the resources and tools that would lead to an integrated, safe, responsible and maintained transportation system, can be identified.

In recent years engineers tend to focus on human and technical errors as causes of accidents. Responsibility for the accident should not be thrown solely on drivers, but also on other elements that build the transport system: planning and maintenance of the infrastructure, organization and traffic conditions in the settlements, increased knowledge of the population and specialists who define harmony in movement and the degree of conflict of infrastructure.

The reduction of casualties on the roads requires the combined efforts of a large number of institutions and the will to undertake specific activities for better performance and decrease errors in system 'Driver - Vehicle - Road'.

This study examines models for prediction of accidents (Accident Prediction Models) for signalized intersections and crosswalks. These models are developed to calculate the likely change in accidents involving motor vehicles and pedestrians and also the degree of risk of accident to one participant, even in case of his transport mode. Large flows of vehicles can often compete with moving pedestrians, mutually cross their planned directions, which in turn leads to delays and creates conditions leading to the separation of the city to different areas.

2. Choice of method for traffic safety evaluation

2.1 General characteristics of road accidents

Scientifically based system for limiting and eliminating the negative effects of the increasing number of vehicles on the road can be built only after a thorough and comprehensive study and analysis of the causes and conditions, facilitating the occurrence of accidents. The analysis of accident allows detection of the organization of traffic and pedestrian flows, verification of planning effectiveness, reconstruction and control events.

The analysis can be done by studying in detail an individual or a group of accidents that occurred on a section of the road network. The purpose of the analysis is to provide information for the majority of accidents to find out whether the statistical data actually contributes to the occurrence of the accident, what are the trends, if this process continues, what to expect, how to concentrate and allocate the available forces and means of prevention.

Traffic safety can be evaluated using statistical data and by measuring the parameters of indirect assessment.

2.2 Statistical Methods

Statistical methods allow researchers to obtain the summary and accurate assessment of road safety and should be used for controls of indirect estimates. The use of these methods is associated with certain difficulties - the need of accident data for 1, 2 or more years, without change in the traffic conditions. Since these methods are used in many countries, there is a possibility to make a comparative analysis of individual indicators.

2.3 Indirect methods

Indirect methods for the evaluation of traffic safety have one very important advantage over statistics – there is no need for data on accidents.

a) Method of conflict points - this method is used to assess the potential risk of an intersection or junction [8, 15]. It has been discovered that the degree of risk of a conflict point of intersection depends on the angle between the trajectories of the two vehicles.

b) Method of conflict situations - this method was proposed by C. Perkins and J. Harris (USA) in 1968. Specialized organizations connected with traffic safety appreciate the positive qualities of the method and it is one of the most used and the most promising for visual assessment of road safety nowadays. According to the authors of the method, conflict situation is a situation that can lead to accidents if the participants do not take protective actions or adequate rescue maneuvers. There are still differences in terminology, methodology and grading the risk of conflict.

c) Method 'sound/noise on acceleration' - the basis of the method lays on the hypothesis that travel is safe and that the relative speed between the vehicles is close to zero. Dispersion of the longitudinal acceleration of the vehicle while driven is used as evaluation indicator. Increase in 'sound/noise on acceleration' is a sign of potential danger to traffic.

d) Methods of complex measurements - in these methods quality parameters are used, which are obtained from the values of the various parameters of the movement - time, path, speed, deviation of the steering wheels etc. [9, 13].

2.4 Registration and analysis of traffic accidents

A traffic accident is an event that occurs during the movement of the vehicle and causes death or injury, damages to the vehicle, road, road infrastructure, cargo or other property damage [12]. The definition shows that in order an event to be classified as a road accident, it is necessary a vehicle movement and harmful effects to take place.

- *Registration and reporting of accidents* - the total number of accidents that are not subject to registration is from 6 to 8 times greater than officially recorded. Although the damages are smaller, their analysis would contribute to a more objective assessment of safety and a more precise determination of the causes for accidents. Accident register is enrolled in the 'traffic police' of the territorial unit. They do not keep records of accidents, which started deliberately in order to suicide, homicide, injury or damage caused by natural disasters and others. Operating services prepare daily, weekly, monthly and annual report of the accident area or for the country. A detailed compendium on traffic accidents' statistics is issued every five years.

- *Analysis of data on accidents* - the main objective of the data analysis for accidents is to obtain complete information on the conditions and causes of accidents. Achieving this goal is limited by two reasons. It is practically impossible to get all the information about an accident because the elements of this event pass irreversibly with time and purely due to technical reasons. The second reason is related to the accuracy of the information and its transmission. The main tasks of the analysis of accidents are: receipt of sufficient quantity and quality of information, processing of the information by various methods (statistical probability, topographical characteristics, etc.), analysis of groups of accidents, analysis of individual accidents.

Quantitative method - the purpose of this analysis is to obtain estimates of absolute and relative indicators of safety using accidents data. Absolute statistical indicators are: total number of accidents, deaths and injuries. They are calculated for a given period and comparing them with past years allows conclusions about the level of safety to be made. The comparison can be done for the same periods between separate administrative territories or countries in comparable conditions.

Topographic analysis - the purpose of topographical analysis is to identify the places where road accidents are concentrated. These places are called black spots, hazardous areas and outbreaks of accident record, but their essence is one - places where accidents occur frequently. Areas with a concentration of accidents can be separated into two groups. The first relates to intersections and junctions, railway crossings, bridges, tunnels and other road facilities. The nature of traffic on such sites is determined uniquely by the highest probability of occurrence of accidents. The second group should join the rest of the roads and streets. Analysis of individual accidents is to identify its causes, mechanisms of development and possibilities for its prevention and to provide a so called expertise of accidents.

2.5 Literature review of sources related to accident prediction models

There is a large number of scientific papers and publications on methods and approaches for assessing road safety and influencing factors. What unites all of them is the search for an appropriate solution for improving road safety depending on individual characteristics: areas designated as hazardous after conducted surveys (black spots or black sites); roads and areas associated with particular types of accidents at a number of individual sites throughout the area.

The issue of safety is reviewed in [4]. The main purpose is development of reliable transport system on the territory of Sofia Municipality in the Republic of Bulgaria as well as detailed analysis of the contemporary transport system and projections for future growth and development of the city. During the development of the plan some key conclusions are made: the density of the road network in the city is unsatisfactory; the structure of the network traffic is not complete; the frequency and duration of trips, as well as the number of private cars, are increased; there is a decline in people traveling by mass public transport at the expense of private car users. The main priorities for the city are to improve the living conditions and quality of the environment in Sofia.

Studies [5], [17] and [18] analyze traffic counts and data of signalized intersections in many urban centers in New Zealand. In different periods of time accident prediction models for common types of accidents were developed. One of these models was adopted in the present article for safety assessment.

Works [10] and [11] reveal that during his study Jackett uses information about accidents, traffic volume data from the environment and geometric data taken for 523 urban roads to calculate average accident levels in order to take timely measures.

Law on Road Traffic and the Regulations for its implementation [12] governs the rules of the road, open to the public, the requirements for vehicles, the requirements for driver qualification, the rights and obligations of participants in the movement and the relevant departments and officials, as well as coercive measures to be applied, and the penalties for violating the contents of this law and the issued hereunder regulations. The purpose of this law is to protect the life and health of the participants in traffic, to facilitate their movement to protect the assets of companies and individuals, and the environment from pollution by motor vehicles.

Labor [7] informs about urban intersections with four lanes in one direction, the most common form of roads in the UK. Accidents at intersections are 1772 over the period of 4 years. Accidents involving pedestrians are more than 28.8% of all accidents.

Labor [16] examines 300 road links between major junctions in the United Kingdom. During the 5-year study 1590 accidents occurred on the territory of these road links. Some of the more important discoveries of the study are that the models predict more than the average number of accidents with links connecting pedestrian crossings than segments without pedestrians in any stock vehicle and pedestrian density; some of the physical variables in the model appear to be related to speed. For example, increased visibility in the opposite direction of travel affects the general increase in accidents, accidents with motor vehicles and accidents with pedestrians.

In labor [2] a deterministic model is developed for accidents with pedestrians and vehicles. According to the study accidents have a random character. The Davis model is designed to allow comparison of the possible accident (reducing effects through a variety of techniques) to 'calm' traffic. It focuses on the volume and speed of traffic, borrowing default values for the other variables: distance from the pedestrian lane before the collision; the speed of a pedestrian moving towards the road; time perception and reaction; reducing speed after brake (braking distance).

Study [14] addresses the measurement of risk, based on the theory that each type of activity is related to exposure to a certain degree of risk. Risk measurement, by distance only, offers a broad risk assessment of accidents. Drivers are exposed to different types of risk while traveling in different sections of a road. Risk and Shaoul (1982) pay attention to the classification of the intersections along the way with different levels of risk based on the number of side roads, expected maneuvers in the intersection and the number of expected points of conflict. They believe that a better level of risk assessment can be achieved if assumptions about the number of movements of pedestrians and traffic on the road segment are made. The models show that the risk to pedestrians increases with the traffic flow, but decreases with increasing number of pedestrians. This effect is called 'safety in numbers'.

In study [3] the safety of pedestrians using crosswalks and signalized intersections is investigated and compared to crossing the street without signaling elements. Labor [4] places a table of studied intersections that is used as a basis for counting the number of transport vehicles and pedestrians. It was found that the data is typical for the selected study area of Sofia, Bulgaria.

It is essential to mention it is advisable that the chosen accident prediction model should be a consequence of expert opinion. This is where the expert evaluation method and its feasibility for analysis

of safety management system can take place. The basic objectives of safety strategy are:

- clear definition of the analyzed problem;

- creation of a certain questionnaire connected to the problem;

- implementation of a poll;

- analysis of poll results.

The method of expert evaluation has been used in a study of Safety Management Systems functioning of a Bulgarian railway carrier. This type of model is proposed in study [6], and it is not applied in road transport in Bulgaria yet. By weighing the expert assessments, calculation of parameters and determining the statistical significance of evaluations, it would be possible to determine the degree of influence of respective factor on operating safety not only in rail, but also in road transport .

3. Accident Prediction Models for vehicles and pedestrians

This paper uses the aforementioned model of work [17], statistical data on volumes of flows of vehicles and pedestrians, taken from the Bulgarian Ministry of Interior and Sofia Municipality and data on the characteristics of the accidents. It was considered that this data is relatively old or less complete, and counting was performed in volumes of flow of vehicles or pedestrians according to the method shown in [18].

Models for predicting accidents (APM) can be implemented by transportation engineers and transport planners to predict the rate of accidents, and to assess the effects of changes in safety at various travel modes.

Accident prediction models can be used to determine the possibility of change in the number of accidents involving a motor vehicle, a pedestrian, also the level of accidents for each street and to change the organization of the movement.

One of the most important reasons for accident modeling is the prediction of the number of accidents. For this reason the task of selecting the most appropriate methodology and feasibility study for implementation in Bulgaria was given.

When it comes to modeling small samples, the Poisson-gamma model (low mean problem) is usually the choice of transportation safety modelers. Other modeling techniques are related to the non-linear models and geographically weighted regressions but according to the works in the field of transport modeling the best model is the basic, which is a regression. That is because of the fact that each of the approaches has its own strengths and weaknesses. Difficulties arise from the collection of extensive statistical database if it does not exist so far.

An examination of the literature and research in the field of models for predicting the number of accidents (Accident Prediction Models) shows that the most widely used model is of the following form [17,18]:

(1) $A = b_0 x_1^{b_1} x_2^{b_2}$,

Where:

A - accidents (number of accidents per year);

x_1, x_2 – traffic flows (total number of vehicles or pedestrians per day);

b_n – parameters of the model.

It could be used with other variables characterizing the influence of other traffic safety factors (width of the roadway, crosswalk width, etc.). This further complicates the model and it will not be used in this article. The coefficients b_0, b_1 and b_2 can be determined by the use of relevant statistical data. Due to incomplete statistics for some accidents involving pedestrians the article checks only the relevance of the above-described model in Bulgaria (using coefficients is proposed in the works [17,18]).

4. Application of accident prediction models for Bulgarian conditions

Accident prediction models can be used to determine the possibility of change in the number of accidents involving a motor vehicle, pedestrians, also the level of accidents for each street and to change the organization of the movement. It could be used for variables characterizing the influence of other factors on traffic safety too.

This paper examines two variants of accident prediction models. For each of the models coefficients proposed by New Zealand authors were selected to check their adequacy for Bulgarian conditions.

Based on the volume data streams of vehicles, pedestrians, and data on the characteristics of the accident the adequacy of the above-described model was examined (expression 1) for the conditions in the country. The daily volume of the traffic flows of vehicles and pedestrians were taken from the Sofia Municipality and enriched by observations (counts) and use of the method described in works [17, 18]. Due to the limited volume of statistical data on the investigated types of accidents (complete data, but only for the years 2009-2012) it was decided coefficients obtained in [17, 18] to be used. The applicability (the relevance) of the models was reviewed and verified for the following types of accidents: Model 1: An accident between a road vehicle that is making right turn and pedestrian crossing the intersection (Fig. 1). The type of the model for this type of collision is as follows:

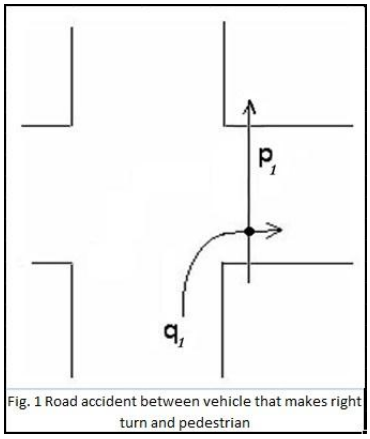

Fig. 1 Road accident between vehicle that makes right turn and pedestrian

(2) $A_1 = 0.000054 q_1^{0.4343} p_1^{0.5127}$,

Where:

q_1 - daily flow of right cornering vehicles for one direction;

p_1 - daily flow of pedestrians in the same direction.

The number of actually admitted and registered by the Police and the State Automobile Inspection (SAI) estimated number of accidents and incidents, obtained by the expression 2, distributed in intervals in accordance with the daily flow of pedestrians are compared in Figure 2.

Correlation between actual and estimated number of accidents in model 1 is shown in Figure 2.

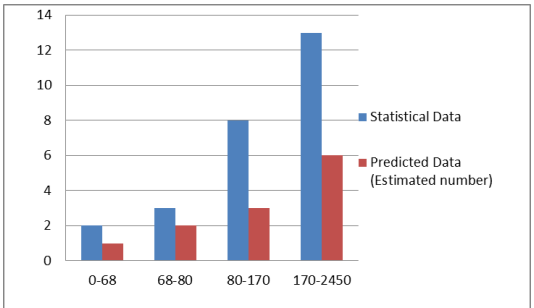

Fig. 2 Accident Prediction Model 1

Model 2: An accident with a transport vehicle and a pedestrian on a walkway (Fig. 3): The type of the model for this type of collision is as follows:

(3) $A_2 = 0.0000306 q_2^{0.6584} p_2^{0.2041}$,

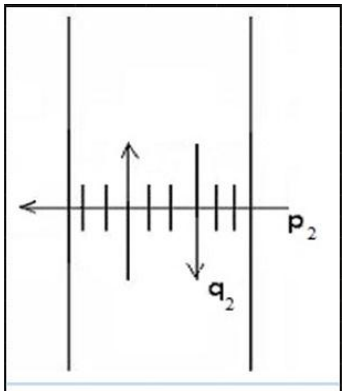

Fig. 3 Road accident between vehicle and pedestrian on a pedestrian crossing

Where:

q_2 - daily flow from motor vehicles;

p_2 - crossing pedestrians.

Figure 4 compares the number of actually admitted and registered by the Police and the SAI accidents and the estimated number of accidents (obtained by the expression 3) distributed in intervals in accordance with the daily flow of pedestrians.

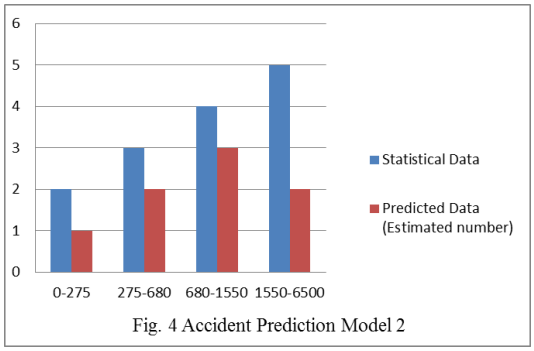

Fig. 4 Accident Prediction Model 2

Studies show that both models work well and can be used to solve practical problems of safety in Bulgarian conditions. The exception is the prediction of the number of accidents involving large volumes of vehicle and pedestrian flows. This fact suggests further research and determination of the coefficients of the models based on more complete statistical data on the number and characteristics of the admitted accidents.

Based on the analysis the following main conclusions can be formulated. First - the analysis of the models found that they generally work well and can be used to predict the safety of vehicles and pedestrians in Bulgaria. Taking into account the safety of this type of road users the following recommendations can be given: development of guidelines to assist local governments in the successful planning and implementation of programs for traffic safety; updating the regulatory framework regarding the terms and conditions of the road; development of programs with concrete measures to improve the organization of the movement. Models for predicting accidents could be used as a basis for helping to reduce accidents involving pedestrians by providing data at what traffic density a number of incidents will occur and how they should be avoided or sufficiently reduced.

5. Conclusion

The forms and types of accident models vary considerably. Individual types of models (e.g. different types of models for each intersection) are of great interest but do not lead to the production of significantly improved model for each accident than the so called 'all accidents model' (basic model). Furthermore, the basic model has proven its stability over the years and enjoys the confidence to predict future levels of safety. The experience in the studies of road accidents shows that they are due to a combination of the following factors: highway geometry, driver and vehicle characteristics and the environment. Accidents are typically caused by an interaction of more than two of these factors. The proposed models can be successfully used in decision making to improve traffic safety in the cities of Bulgaria where it is necessary to estimate the potential number of accidents that could be expected at a given workload of the respective intersection.

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