MAIN ISSUES, TRENDS AND RESEARCH GUIDELINES TOWARDS TRAFFIC SAFETY

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Abstract: *The rapid development of road transport and serious reliance of modern human society on its services is an undeniable fact. At the same time, the past and present of this transport mode are inextricably linked to a number of problems related to traffic management. Therefore, the need of development and implementation of effective measures to increase the level of traffic safety becomes more important.*

These measures should be fulfilled at different organizational levels (e.g. urban planning, improvement of organization and traffic management systems, vehicle design, transport infrastructure, etc.). Undoubtedly, the most important of them are connected with traffic flow characteristics, which require a profound analysis, especially about their connection with safety requirements.

In this sense, the present article discusses the relation of operational safety with the potential of conflicts between road users (conflict situations) due to the impact of some influencing factors. These factors include: state and/or local policy on road safety, characteristics of traffic flows, technical features of vehicles, human behaviour, weather conditions, traffic management, etc. In the context of said above, here several approaches for analysis and evaluation of road transport safety have been considered. Their strengths, weaknesses, applicability and need to develop are also discussed.

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

1. Introduction

The rapid development of road transport and the strong reliance of modern human society on its services is an undeniable fact. At the same time, the past and present of this type of transport are inextricably linked to a number of problems of organization and traffic safety on the roads and streets. For example, in 2009 more than 35,000 people were killed in traffic accidents on the roads of the European Union (Fig. 1) and about 1.5 million were seriously injured. Property damages are enormous and estimated at not less than 130 billion EUR [9].

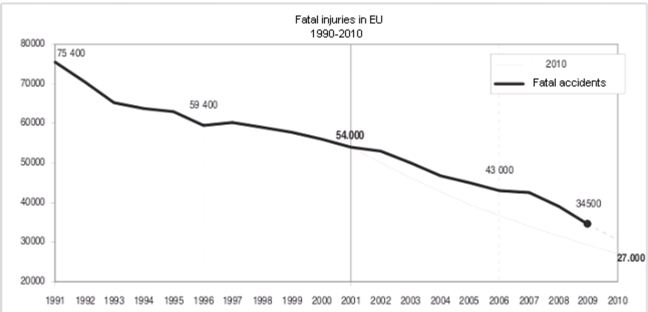

Fig.1

All this raises the need to develop and implement effective measures to increase the level of traffic safety. These measures should be implemented at different levels (e.g. urban planning, improving systems of organization and traffic management, design, construction and improvement of the transport infrastructure, etc.) and no doubt require in-depth research to identify of the laws and the characteristics of the movement of vehicles. What is essential in this aspect is the study of the impact of various operating parameters (e.g. the characteristics of traffic flows, the specifics and technical condition of transport infrastructure, organization and management of traffic flows, etc.) on safety.

The analysis of current approaches, concepts, research results and directions for future research in the area of transport safety is the main goal of this article.

2. Nature and characteristics of road transport safety

Road transport safety is a complex concept, which involves all available approaches, methods and activities for management of risks aimed at road participants (drivers of vehicles, passengers, pedestrians, etc.), material assets (vehicles, transport infrastructure, etc.) or the environment.

Typical feature of transport is the movement of physical objects (vehicles). Conflicts between them are highly undesirable events and their prevention (or reducing consequences after their occurrence) is a main priority in systems for traffic organization and safety management.

Operational environment with potential for conflicts between road participants (conflict situation) may occur due to the influence of a number of factors. These factors include: state and / or local policy on road safety, the characteristics of traffic flows, the technical condition and the characteristics of vehicle and road network, human behavior, weather, organization and management of traffic and more. Figure 2 shows the correlation (and interaction) between the influencing factors on road safety known as: Driver - Vehicle - Road - Environment (operating conditions) System.

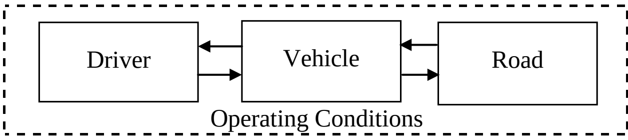

Fig.2.Driver - Vehicle - Road System

It should be recognized that there are a number of scientific studies on the negative impact on road safety of the mentioned above factors. Figure 3 shows the proportion of different factors to the occurrence of road accidents according to the data proposed in [8].

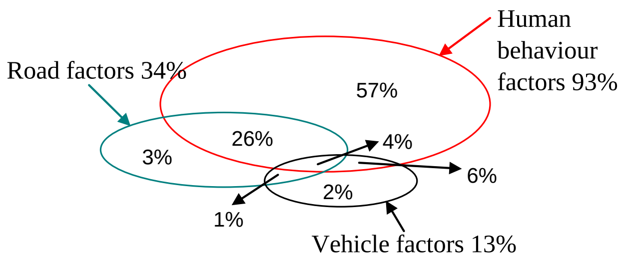

Fig.3.Proportion of different factors influencing traffic safety

A specific feature of road transport is the large number of interacting vehicles moving in different directions. If in the course of its movement, two (or more) vehicles simultaneously "bring intention" to "occupy" the same restricted area, an unusual (complex) operating situation occurs with a potential for conflict between these vehicles. Further development of the complicated situation may be terminated as a result of timely and adequate actions of drivers of vehicles. If the behavior of drivers is inadequate, the complicated situation could easily develop into an emergency situation (potentially dangerous situation) that requires immediate action and high professionalism of the drivers to avoid conflict (traffic accident), for example: a sudden change of speed or movement direction, extreme (emergency) braking, etc.

It should be noted that the occurrence (and also the development) of a potentially dangerous situation largely depends on the traffic organization, the characteristics of traffic flows, the weather and the condition of the transport infrastructure. Even the smallest changes in the characteristics of these factors lead to significant changes in the parameters of the traffic, and hence the probability of occurrence of abnormal and emergency situations. This should be taken into account when conducting research on road safety: approaches, methods and models for analysis and forecasting, analysis and evaluation of influencing factors, choice of the most appropriate measures for increasing safety, etc.

3. Overview of Approaches for the Analysis and Evaluation of Road Transport Safety

There are a large number of scientific papers and publications on methods and approaches for assessing road safety and influencing factors. What unites them all 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 typical with particular accident types at a number of individual sites throughout the area.

In this part, the article will concentrate on some basic methods and traffic safety models with the aim of clarifying their advantages and disadvantages. Thus, the main factors that influence traffic safety and the fundamental models used around the world and in the European Union will be determined.

Each local authority in the European Union under the Road Traffic Act is required to improve road safety. In fulfilling these responsibilities, public funds are invested in projects aimed at analysis, evaluation and improvement of road safety and necessity to take measures for reducing road accidents. Improved flow should lead to: decrease of travel time, vehicle emissions, fuel usage, psychological stress on drivers, and improved safety.

In order to create a suitable transport approach (model) for prediction of traffic accidents it is necessary to answer to a few basic questions:

- Influential Factors: Which engineering factors influence accidents rate. Are these factors the same or different from those found in past studies?
- Extent of Influence: Does each influential factor affect accidents and to what extent? Which factors are not significant, marginally significant, or very significant?
- Possible Countermeasures: What are the engineering treatments for addressing specific safety problems?
- Efficacy of Countermeasures: What are the traffic accident reduction factors. For example, how many lives can be expected to be saved for every 1 m increase in shoulder width? [3]

According to reference [3], factors that influence traffic safety include: engineering (roadway) features, vehicle and operator characteristics, environmental features, and levels of education and enforcement of legislation geared towards safe road use. The study focuses only on the engineering features of the road (Fig. 4).

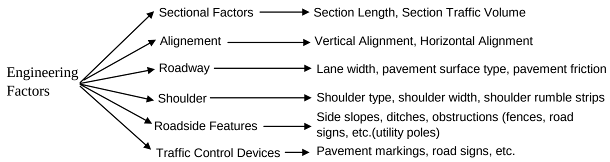

Fig.4.Explanatory Engineering Factors Affectig Crashes

Traffic accident prediction models are developed for each highway functional class for four traffic accident severity categories: injury traffic accident; property damage only traffic accidents; fatal and injury traffic accidents and total traffic accidents. Based on this set of information, the factors affecting traffic accident occurrences are defined: the section length, traffic volume, lane and shoulder width, pavement friction, average horizontal curve radius, average vertical grade, driveway density.

Prerequisites to traffic accident modeling basically include developing a traffic accident database (with roadway characteristics such as traffic volumes, geometric design features, traffic control features, and traffic accident history) and selecting an appropriate functional form.

According to reference [4], despite numerous findings made in improving the estimation tools of statistical models, the most common probabilistic structure used for modeling motor vehicle traffic accidents remains the traditional Poisson and Poisson-gamma (or Negative Binomial) distribution.

For example, study [3] shows the use of Poisson and Negative Binomial models. It is made for rural two-lane roads in Indiana. Each of 540 rural two-lane state highway segments and a sample of 107 county road segment lengths are explored for the period from 1997 to 2000. Four functional classes are studied: rural collectors, rural minor arterials, rural principal arterials on the state highway system, and county roads.

The general form of traffic accident models derived using a Poisson model is:

$$A = kLQ^{\beta} \exp\left(\sum \gamma_i \chi_i\right), \quad (1)$$

where:

A - number of traffic accidents in a selected time period;

L - length of the section;

Q - average daily traffic on the section;

χ_i - explanatory variable;

k , β , γ_i - constants estimated from the modeling process.

Negative Binomial model allows additional variance representing the effect of omitted variables. Using negative binomial regression analysis, some traffic accident prediction models for three different traffic accident severity categories are obtained – all traffic accidents, property damage only traffic accidents, traffic accident, fatal and injury traffic accidents.

Negative Binomial Regression and Poisson regression are also used as base approaches in [6]. In this study, D100/22 State highway section on the way to Şebinkarahisar (Turkey) is examined. The number of traffic accidents in accordance to kilometer and geometrical properties of the highway, environmental, highway and traffic signs condition, field conditions at night and during daytime, are taken into consideration.

When it comes to modeling small samples, the Poisson-gamma model is usually the choice of transportation safety modelers. Poisson-gamma models problems, defined as the "low mean problem" (LMP) are the topic in [4].

The primary objective of this research project was to verify whether the LMP affects the estimation of the dispersion parameter and, if it was, to determine the magnitude of the problem. To accomplish the objective of the study, a series of Poisson-gamma distributions were simulated using different values describing the mean, the dispersion parameter, and the sample size.

The functional form of the model is:

$$B = \beta_0 F_{i,1}^{\beta_1} F_{i,2}^{\beta_2}, \qquad (2)$$

where:

B - predicted number of traffic accidents for the site i;

$F_{i,1}$, $F_{i,2}$ - entering Annual Average Daily Traffic flows for the major and minor approaches for site i;

β_0 , β_1 , β_2 - coefficients to be estimated.

Although the functional form is not the most adequate for describing the relationship between traffic accidents and exposure, it is still the most favored by transportation safety modelers for modeling traffic accident data at intersections. There are three estimators that are commonly used: the Method of Moments, the Weighted Regression, and the Maximum Likelihood Method. What is essential to know is that, if the dispersion parameter is misestimated, common analyses performed in traffic safety could be seriously undermined.

Another study uses Generalized Linear Model Technics [5]. This study is based upon data of personal injury road accidents reported to the Police which occurred on the Lothian major road network during a four year period 1979-1982. A computer program called GLIM (Generalized Linear Interactive Modeling) was adopted for the study and the purpose of the model was to explore the relationships that may exist between road accidents and traffic flows on different parts of the road network. To obtain appropriate data it was necessary to have both road accident and traffic flow information. The LORASS (Lothian Road Accident Statistics System) was the chosen software because it provided a comprehensive source for such data. Another computer program, called TRAMS (Transport Referencing and Mapping System) was installed by the Region to support this model of the road network.

Each junction is identified by its LORASS node number and the software GLIM does not simply represent a complex junction as a single node but a series of nodes each showing particular traffic conflict points. One disadvantage of the technique is that LORASS codes are not universally accepted, i.e. determined to some extent by the subjective judgment of the researcher. Another difficulty is related to the investigation of accidents- the study data have a marginally higher proportion of accidents at junctions than those for Great Britain. This observation may be explained by the relatively high proportion of urban road miles in Lothian Region, suggesting a higher than average number of junctions per road kilometer.

Generalized Linear Modeling Approach in which Negative Binomial (NB) regression models is used in [2]. This model is developed for the City of Toronto and the variables that had significant effects on accident occurrence are: the number of households, major road kilometers, vehicle kilometers travelled, intersection density, posted speed and volume-capacity ratio.

A Geographic Weighted Regression (GWR) approach is employed to test spatial variations in the estimated parameters from zone to zone but it is a relatively new technique that permits the parameter estimates to vary locally rather than globally. The basic idea of GWR is that a regression model is fitted at each point, i.e., weighting all observations by a function of distance from that point. The major disadvantage of the GWR method, and its software, is the assumption of normally distributed errors which are not valid for accident prediction modeling.

It is important to mention that, data availability and logical considerations influenced the process used to select the independent variables in the models. However, it is recognized that a model with too many variables may perform poorly with a new sample of data from the same population. Description of statistic data in [2] is divided by: socioeconomic and demographic characteristics, number of intersections, road kilometers, traffic demand and variables.

Another case study that uses data for more than 1000 Traffic accidents in Southern California identifies twenty-one traffic flow regimes for three different ambient conditions: dry roads during daylight, dry roads at night, and wet conditions [1]. This research uses a disaggregate approach, in which the units of analysis are the traffic accidents themselves, rather than aggregations of traffic accidents over time and space. There are three sets of variables in the disaggregate approach: the characteristics of the traffic accident and of the traffic flow, the time of the traffic accident, measured at a location as close to the site of the traffic accident as possible, and environmental conditions, such as highway geometry, roadway and weather conditions, and visibility.

Two of the methods used are linear: principal components analysis, the most common form of factor analysis, and cluster analysis.

Principal components analysis is used to interpret the correlation structure among traffic flow variables in terms of a smaller number of independent linear combinations, called factors.

Cluster analysis is a similarly widely used method of grouping observations based on similar data structure. This analysis is used in order to find homogenous groups of traffic flow conditions, which they call "regimes."

The third type of multivariate analysis is Nonlinear (Nonparametric) Canonical Correlation Analysis (NLCCA), which is not commonly used in transportation research. NLCCA is designed for problems with variable sets that contain categorical or ordinal (Nonlinear) variables. The analysis techniques are somewhat unconventional to this domain of study. This analysis applies only to urban freeways with at least three lanes in each direction, and the specific results apply to conditions during 1998 in Orange County, California, but validation has not yet been conducted, so the degree of spatial transferability cannot be confirmed.

There are various other different approaches for analysis and evaluation of road safety.

In reference [7] are considered 23 different approaches. "Risk Evaluation by Modeling of Passing Behaviour", is about overtaking maneuvers on rural roads, based on road geometry and driver characteristics (ages and gender). The negative aspect in relation to EURSI (European Road Safety Inspection) is that it addresses only one type of a collision scenario. It's the same with the following projects: "Assessing Traffic accident Risk on Road Curves", "Effects of Geometric Design Consistency on Road Safety", "Roadside Point Hazards"; "5-level Roadside Hazardousness Index".

Approaches used for the analysis and evaluation of road transport safety are: different safety indexes ("Safety Assessment on Accidents, Traffic Flow and Facilities"), General Linear Regressions ("Effects of Geometric Design Consistency on Road Safety"). Hierarchical Full Bayesian models were developed to relate traffic accident frequencies with various risk factors associated with adverse weather, road alignments and traffic characteristics in "Bayesian hierarchical approach for developing safety performance functions", Empirical Bayesian algorithm is used in "TARVA", Data Collections based on GPS based surveys is used in "Web GIS for Road Risk Analysis" and so on.

3.1 Strengths, weaknesses and applicability of the Approaches

We can conclude that in terms of approaches for assessing road safety, there are various different approaches to predict accidents, but they can be generalized to the following main types of modeling techniques: Generalized Linear Modeling, Poisson and Negative Binomial model. There are also a few innovative ways of modeling traffic safety, such as the nonlinear (nonparametric) canonical correlation analysis, Generalized Linear Interactive modeling and the use of GIS in transport safety which are usually a collaboration of the well-known above models. Each of the approaches has its own strong points and weaknesses. In most approaches, difficulties arise from the collection of extensive statistical database if it does not exist so far.

The Generalized Linear Interactive modeling that is proposed in [5] is a flexible model from the viewpoint of the possibilities that it suggests. It has the same weakness as others like this: contains a common component on both sides of the equation. This problem exists in the analysis of relationships, for example: between accident rate and traffic on links where the dependent variable would be accidents per million vehicle kilometers and the independent variable would be million vehicles. According to the research significant improvements to the models are achieved by the application of empirical Bayesian methods. Interestingly, in the research, the accident rate was found to decrease with increasing traffic intensity.

As regards Poisson and Negative Binomial model, which are used in a variety of studies (for example reference [3]), the proposed models suggest additional possibilities with suitable set of variables. The difficulty appears with the data collecting, the selection of significant and the definition of insignificant variables and also the estimation of parameters of the model for conditions outside Indiana. We can rightly conclude that the negative aspects of Poisson- Gamma models, discussed in [4], are the same together with the fact if the dispersion parameter is misestimated, common analyses performed in traffic safety could be seriously undermined. In scientific papers [6] and [1] the advantages of the models are related to the possibility for establishment of elaborate transport model, influenced by a sufficient number of variables. The researcher concludes that it is crucial to take into account traffic accidents report, environmental conditions and highway geometric characteristic to determine the risky and dangerous sections on interurban highway. In this way all of the effects caused traffic accidents would have been taken into consideration.

When talking about Nonlinear (Nonparametric) Canonical Correlation Analysis (NLCCA) [1], which is a disaggregated approach united to cluster analysis, disadvantages are related to the collection of statistical information and the complexity of the model, because the cluster needs grouping of the variables, which could be partially subjective.

Some authors prefer to use more types of parallel but separate techniques. This is the case in [2]: the model mainly depends on variables, which are not generally known and are obtained according to the specific conditions. The major disadvantage is the assumption of normally distributed errors.

4. Conclusion

The forms and types of accident models vary considerably. It has been shown that 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". Furthermore, the "all accident model" has proven its stability over the years and enjoys the confidence to predict future levels of safety.

Experience in the studies of accidents at roads 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 process of collecting crash database is expensive and needs to contain descriptions on the following: date, time, location of the traffic accident; number of injured and vehicle involved; accident severity; drivers physical condition; light and weather conditions; collision type; distance from the intersection; roadway segment length; traffic flow; surface type and so on. The difficulty of creating models derives from the large number of experimental data, which needs to be collected and correctly assessed.

The present state of the art in the field of traffic safety shows that the negatives of most developed models are associated with their severe individuality, i.e. the need to do the research for small areas because of labour intensity in the collection of information. The models' results depend mainly on variables which are generally known and are prepared according to the particular conditions. The key difficulty comes from the need of collecting complex and considerable amount of data most of which include significant and insignificant variables. Despite numerous studies, the identification of significant and insignificant variables is difficult and to some extent subjective, and therefore care must be taken at the same time not to aggravate the model, but to be made enough accurate for the conditions.

As for Bulgarian conditions, modeling the influencing factors on road safety is not at the core of planning and management of urban traffic. In other words, the correlation of known and discussed in this article approaches and methods for Bulgarian conditions is not checked. The main problem here is the collection and processing of a sufficient number of real data on the characteristics of accidents (number, type, location, etc.), transport infrastructure, traffic flows, etc. It is necessary to analyze and verify the applicability and the need for improvement (for the conditions of country) of the available methods and models in this area. Achieving this goal will contribute to improve the level of transport reliability and safety.

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