



# DETECTION AND ASSESSMENT OF SAFETY PROBLEMS WITHIN ROAD TRANSPORT DECISION-MAKING

**Nikolay Georgiev**

“Todor Kableshkov” University of Transport, Sofia, Bulgaria

**Violina Velyova**

“Todor Kableshkov” University of Transport, Sofia, Bulgaria

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## **Abstract**

*The transportation system safety in many countries often constitutes the largest public-sector problem. This problem is characterized by the presence of a variety of potential negative events that could occur (including their causal factors), the complexity of their detection and stochastic nature of their consequences. The planning and management process concerning transport safety requires that engineers collect and maintain traffic safety data, identify hazardous locations, conduct engineering studies, and establish project priorities. In this regard, the article discusses most common technical and technological factors affecting transport safety and the role of road infrastructure in road accident occurrence. For the purpose of design and maintenance of a successful transport management an exemplary procedure for estimation of transport infrastructure improvement on traffic safety is considered. All above-mentioned could be done in a successful manner just by the usage of scientific approaches and methods. The present paper discusses the essence of some scientific methods, and possibilities to be adapted for the purpose of a successful decision-making in the area of transport safety.*

**Keywords:** traffic safety, hazardous locations, decision making, scientific approaches and methods

## **1 INTRODUCTION**

The transportation system safety in many countries often constitutes the largest public-sector problem. The planning and management process concerning transport safety requires that engineers collect and maintain traffic safety data,

The address of the corresponding author:

**Nikolay Georgiev**

[ngeorgiev60@gmail.com](mailto:ngeorgiev60@gmail.com)

identify hazardous locations, conduct engineering studies, and establish project priorities. The article discusses most common technical and technological (engineering) factors affecting transport safety and the role of road infrastructure in road accident occurrence. For the purpose of design and maintenance of a successful transport management, all the main operations that should be performed are given and an exemplary procedure for estimation of transport infrastructure improvement on traffic safety is considered. The



article also discusses the essence of some scientific methods, and possibilities to be adapted for the purpose of a successful decision-making in the area of transport safety in Bulgaria.

## 2 FACTORS AFFECTING TRAFFIC SAFETY

The operating environment of potential conflicts between traffic participants could be the result of the influence of several factors. These factors include: state and/or local policy on road safety, the characteristics of traffic flows (traffic intensity, speed, density and composition (structure)), vehicle characteristics and human behavior weather conditions, organization and traffic management, etc. The interaction between these factors is derived from the 'Driver-Vehicle-Road' system in the context of the environment (working conditions). (Georgiev, 2007)

Statistically significant relationships can be established between accident frequency and traffic flow, for a variety of site categories. The main factors on the occurrence of human error resulting in an accidents involving a vehicle are: the alcohol intake (in one-third of the cases), the speed chosen by the drivers, the level of attention allocated to the driving task and the level of experience of the road users. Factors affecting traffic safety that are connected with the road conditions and other infrastructure are also known as engineering factors. They are technical and technological factors which can be divided into 6 main groups: connected with road segment or intersection (length of the road segment, traffic volume, etc.), connected with the alignment (vertical or horizontal), connected with road shoulder type and width, connected with infrastructure characteristics (side ditches, barriers, fences, etc.), devices for traffic control

(road signs, road markings) and technological factors such as guidance devices. Engineering factors are exactly the ones that are of main importance because they can be changed to a certain extent and therefore managed. (Sinha & Labi, 2007), (Nambuusi, Brijis, & Hermans, 2008), (Canale, Leonardi, & Pappalardo, 2003).

## 3 PROCEDURE FOR SAFETY IMPACT EVALUATION

For the evaluation of safety impacts of engineering factors on the accident occurrence in this part of the article the main operations in successful safety management cycle are discussed (fig. 1) (Safety Management Cycle, 2015) and a procedure for the estimation the impact of road intervention (fig. 2).

The main operations in Successful Safety Management are connected with continuous updating of the data about black spots, accident reduction factors, the condition of road infrastructure, policies for traffic regulation and continuous training of road users.



Figure 1 Main operations in successful management cycle

All approaches and accident prediction models can be assigned to '4. Monitoring of the accident

factors and tracking changes in the operational environment' and '5. Appropriate Actions'. The Decision-making procedure for traffic accident reduction is shown in fig. 2

Based on the theory (Sinha & Labi, 2007), a summary procedure for estimation the impact of road interventions is shown in fig. 2.

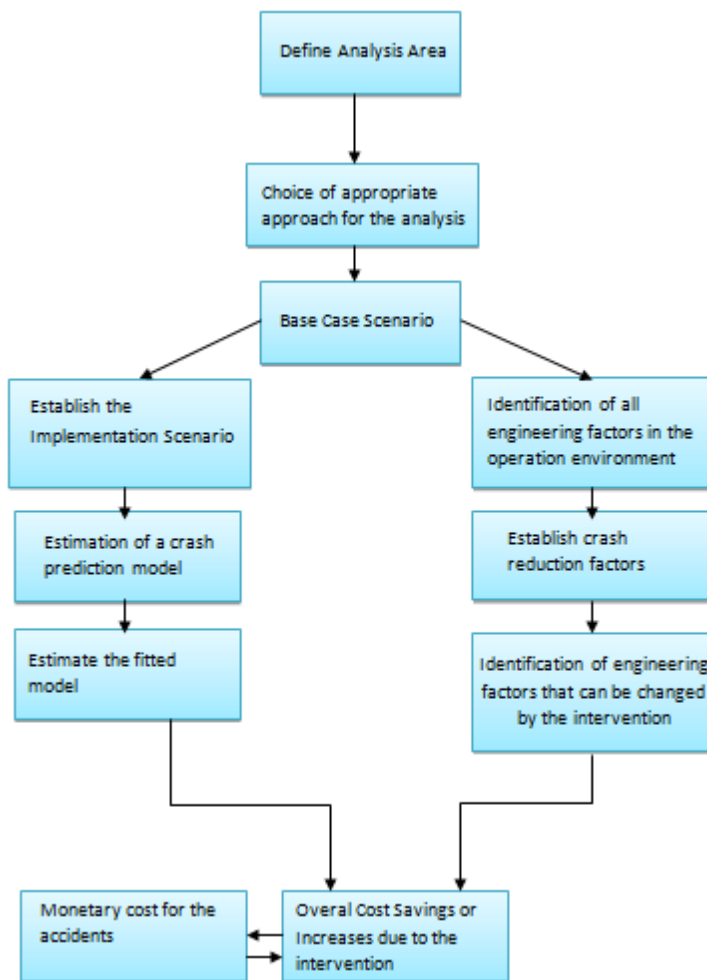


Figure 2 Decision-making procedure for estimation the impact of road interventions

Evaluation of the impact of different factors on safety levels (number of road crashes) is crucial for the comparison of 'with' and 'without improvement' road conditions or scenarios. The summary procedure is connected to the solution of three tasks:

- determining engineering factors and the extent to which they affect the road safety (individually or in combination),
- evaluation of each unit change of the engineering factors on crash reduction,

- from the first two points, evaluating the predicted accident number and possible change expected due to a certain intervention. How will this intervention affect the overall monetary cost of the accidents on a given intersection?

All tasks in the procedure are connected together for the purpose of safety improvement and can be explained as follows:

*Defining the Analysis Area* - which is the specific transportation facility that is going to be analyzed - road section or intersection, or sections or intersections of the same type?

*Choice of an appropriate approach for the analysis* - the choice of adequate approach is crucial for the research. Some approaches may be used often but this does not mean that they are the best for the field scenario. There is 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 associated with particular types of accidents at a number of individual sites throughout the area, etc.

*Establish the base case scenario* - the choice of scenario that is going to be evaluated.

*The left part of fig. 2:* Establishing the implementation scenario is a subtask, connected with certain differences and specific conditions connected with the area of evaluation. The next step is the choice of appropriate model and estimation of a crash prediction model based on the chosen approach. A few of the factors may be insignificant for the model and that is why estimation of the fitted model is important.

*The right part of fig. 2:* Identification of all engineering factors in the operation environment, establishing crash reduction factors and

identification of those which can be changed by a certain intervention, are crucial steps for the accident prediction models' implementation.

The final part of the procedure is to gather information about the monetary cost of the accidents used for the evaluation of monetary losses from the accidents and after that determining the overall cost savings or increases due to the partly intervention on the infrastructure.

#### 4 CONTEMPORARY STATE OF TRAFFIC SAFETY IN BULGARIA

The increasing number of vehicles shows that by 2030 it will exceed 1.2 billion cars (World Book Inc., 2001)

Compared to other European countries, by the index number of killed in road transport accidents per 1 million inhabitants, Bulgaria occupies the unsatisfactory position on traffic safety with about 1000 people killed in road accidents per year. In Bulgaria, more than two-thirds of injuries and 40% of deaths in road accidents were registered in urban areas (dokkpbdp, 2016). Statistics is kept mainly about traffic accidents connected with speeding, wrong overtaking and passing in the opposite traffic lane, withdrawing priority of vehicle or pedestrian, and alcohol intake.

Over the past three years, the greatest number of accidents have occurred on the first class roads. In 2015, accidents on the highways have increased compared to third class roads and municipal ones.

The main urban transport problems in Bulgaria can be reduced to *traffic congestion, environmental pollution, unreliable public transport and low level of road safety*. (Georgiev, 2007).

#### 5 SELECTING AND ADAPTING ACCIDENT PREDICTION MODELS FOR INTERSECTIONS IN SOFIA, BULGARIA

Making efforts of authorities to establish measures for accident reduction and evaluation of the key causal factors are of most importance for the creation of safer traffic conditions. For this purpose, the article aims at selecting and checking

the applicability of appropriate accident prediction models for the territory of Sofia, Bulgaria. A study of various scientific papers and research in the field of accident predicting models shows that the most often used form of model is (1), (Nambuusi, Brijis, & Hermans, 2008) and (Canale, Leonardi, & Pappalardo, 2003):

$$Y_i = e^{(b_0 + b_1 X_1 + \dots + b_n X_n)}, \quad (1)$$

where:

$Y_i$  – estimated number of accidents (dependent variable);

$X_1, X_2, \dots, X_n$  - independent variables of the model;

$b_0 \dots b_n$  - coefficients of the equation to be estimated by the model.

The evaluation procedure is used to derive the regression coefficients and it is directly dependent on the accepted type of distribution of  $Y_i$ : lognormal regression models and log-linear Poisson models. For the purpose of the article, lognormal regression model for accident prediction is selected, which accepts that the number of accidents is log-normally distributed and this guarantees that the results for the predicted number of accidents will be positive number.

After analysis of the most commonly used technical and technological (engineering) affecting safety factors, the following ones are used in the models: average daily traffic (vehicles/day) on the major road and on the minor road, lane number of the major road and of the minor road, lane width (meters) of the major road and of the minor road, existence of separate lanes for right turn of the major road and of the minor road. Initially, 14 causal factors (model variables) have been considered and analyzed by the usage of multi-factor analysis. Subsequently, some of them have been estimated as very poorly influencing factors and excluded from the model.

There were fitted two models regarding *four-leg signalized intersections* and *three-leg stop/signalized intersections*.

The first type of model is based on data about accidents number with fatalities, traffic and

infrastructure characteristics of 76 four-leg signalized intersections in Sofia. The second model is based on the same data for 60 three-leg stop/controlled intersections. Other types of intersections are not subject to the current article.

For the purpose of models fitting a specialized software was used - Statistica 7. Based on equation (1) the two models were verified and their applicability (adequacy) was proved:

**Model 1: Road accidents with fatalities on four-leg signalized intersections**

After the conducted research for this type of model the following form was obtained (2):

$$Y_1 = e^{(-0.102071 + 0.000036X_1 + 0.0000270X_2 - 0.023147X_3 - 0.019034X_4 - 0.102494X_5 + 0.204026X_6 + 0.059099X_7 + 0.020106X_8)} \quad (2)$$

where:

$Y_1$ - predicted number of road accidents with fatalities for four-leg signalized intersections;

$X_1, X_2, \dots, X_n$  - independent variables of the model;

$b_0, b_1, \dots, b_8$  - coefficients of the model to be estimated;

- by adding one more separate lane for a right turn movement of the minor road, accidents number can be reduced by more than 0.10;
- an extension of the lane with 25 cm of the minor road leads to accidents number reduction by more than 0.20;
- if the number of major road lanes increases by 1, the accidents number can be reduced by more than 0.25.

Table 1. Results for the Accident Prediction Model for Four-leg Signalized Intersections in Sofia, Bulgaria				
	Estimated	Standard error	t-value df = 72	p-level
$b_0$	-0.102071	0.46413	0.0000001	1E-09
$b_1$	0.000036	1E-09	0.0000001	1E-09
$b_2$	0.000027	0.01801	5E-08	1E-11
$b_3$	-0.023147	0.02207	5E-08	1E-08
$b_4$	-0.019034	0.09329	1E-11	5E-06
$b_5$	-0.102494	0.14565	5E-08	1E-09
$b_6$	0.204026	0.14565	7E-09	2E-10
$b_7$	0.059099	0.05446	6E-11	5E-08
$b_8$	0.020106	0.0591	7E-10	7E-09

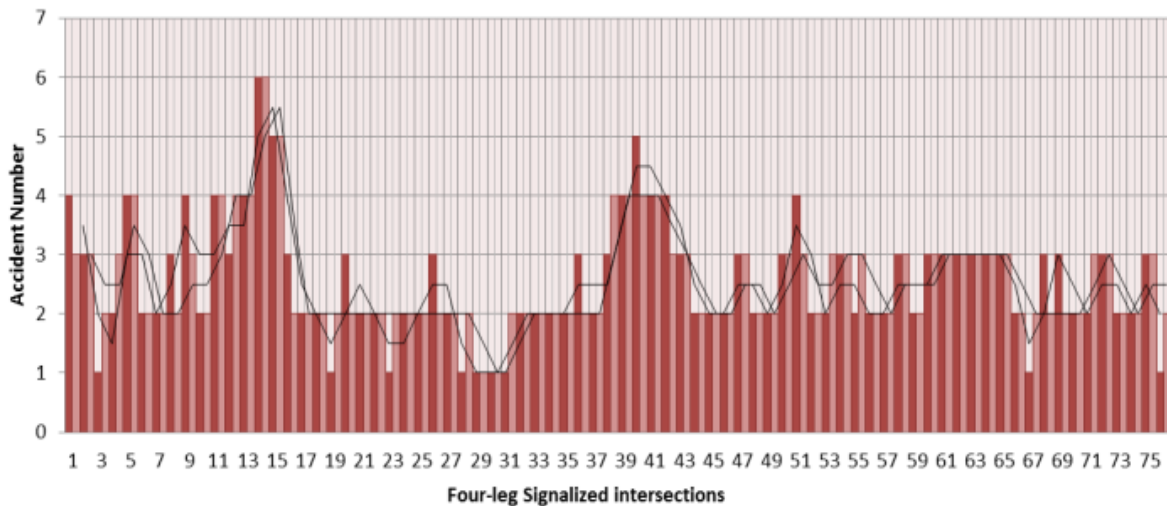


Figure 3 Accident prediction model for four-leg signalized intersection in Sofia

The computation results relating the model are shown in table 1 and figure 3. The comparison between actual statistical data and data derived from the model is shown in fig. 3.

In summary, when changing only one variable and under equal other conditions the following results are received:

A combination of all above-mentioned interventions (changes in the engineering factors) may lead to significant reduction of the number of accidents.

**Model 2: Road accidents with fatalities on three-leg stop/signalized intersections**

This model has the following form (3):

$$Y_2 = e^{(-0.314489+0.000056X_1-0.000002X_2+0.017336X_3-0.007231X_4+0.503134X_5-0.46575X_6+0.001272X_7+0.097021X_8)}$$

where:

$Y_2$  - predicted number of road accidents with fatalities for three-leg stop/signalized intersections;

$X_1, X_2, \dots, X_n$  - independent variables of the model;

$b_0, b_1, \dots, b_8$  - coefficients of the model to be estimated.

The results relating the model are shown in table 2 and figure 4. The comparison between actual statistical data and those derived from the model is shown in fig. 4.

Table 2. Results for the Accident Prediction Model for Three-leg Stop - Controlled Intersections in Sofia, Bulgaria

	Estimated	Standard error	t-value df = 51	p-level
$b_0$	-0.314489	0.5789	7E-09	8E-10
$b_1$	0.000056	1E-13	1E-13	1E-10
$b_2$	-0.000002	7.5E-07	2E-12	5E-12
$b_3$	0.017336	0.01441	1E-10	1E-10
$b_4$	-0.007231	0.03808	4E-11	0.000000001
$b_5$	0.503134	0.20534	4E-10	1E-12
$b_6$	-0.46575	0.24316	1E-09	0.000000001
$b_7$	0.001272	0.05049	1E-11	0.000000001
$b_8$	0.097021	0.09702	1E-09	1E-11

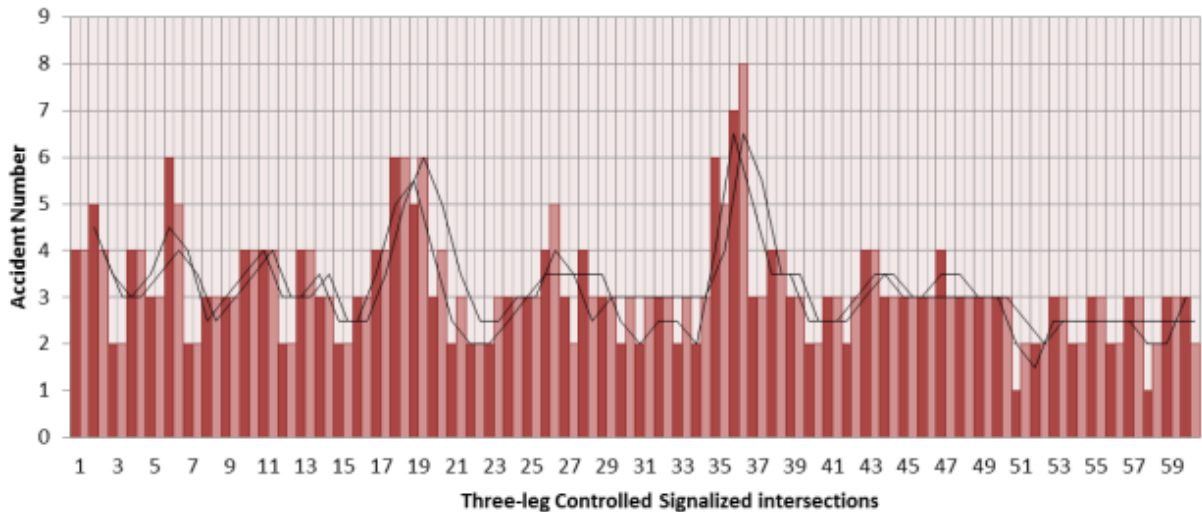


Figure 4 Accident prediction model for Three-leg Stop - controlled intersections in Sofia

For the results of this model, it can be said that an extension of the minor road by 25 cm gives an accidents number reduction by more than one-third.

Any increase (even great) of the average daily traffic of minor road does not lead to a crucial growth of the number of accidents with fatalities.

On the other hand, in the case of an increase of the average daily traffic of major road by 2000 vehicles/day leads to an increase in a number of accidents with fatalities by 2 or more accidents.

## 6 CONCLUSIONS

The proposed procedure and accident prediction models could be successfully used in decision making to improve traffic safety in cities where it is required to estimate the potential number of accidents that are expected to occur at a certain intersection.

By the definition of the main technical and technological factors affecting safety and collection of needed statistical information, traffic safety can be seriously improved which will result in a general reduction of road accidents number and their consequences (fatalities, injuries, material loss).

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