A CONTRIBUTION TO METHODOLOGICAL APPROACH OF TRAFFIC SAFETY ANALYSIS

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Abstract: *When analyzing an area of road safety an important role has methodological approach. Analysis of security in some cities has clearly evident need for well practice methodology, monitoring and preventive package of measures intended to protect all categories of road users. Many years of monitoring and analysis of temporal and spatial distribution of traffic accidents make it possible to detect the laws of motion and thus include the total knowledge of the phenomena that are a prerequisite for the successful operation of a society. This study gives a possible approach for a specific area by analyzing the current situation of traffic safety with appropriate measures for improvement.*

Key words: TRAFFIC ACCIDENTS, TRAFFIC SAFETY, STREET NETWORK

1. Introduction

It is difficult to coordinate the traffic expansion with its control and safety, which resulted in increased number of traffic accidents, material damages and death toll. In the very beginning of traffic development there was no significant research influencing the safety level; the traffic was based on common sense [1]. Unfortunately, our understanding of the complexity affecting the traffic safety is not enough to solve the problem, so it is necessary to replace that kind of understanding with proper data and technical analyses [2]. Incapacity of the science to interpret all the accidents and their causes as well as unwillingness of the society to prevent the accidents have resulted in the delusion that a traffic accident is an ''accident'', i.e. that it happens accidentally, that it is caused by some external influences, and that it cannot be prevented. This delusion was so widespread that it brought about passivity and the lack of ambition to improve the traffic safety in many countries including Serbia.

Each year over a million people die, around 3,000 people die every day and tens of millions are injured in traffic accidents all over the world's roads. In 2000 the injuries caused by traffic accidents were the ninth cause of working disability, and it is estimated that they will be the third by 2020 [2]. The money invested in the traffic safety is relatively small especially in developing countries. For instance, about $0.07 and $0.09 are spent per capita in Pakistan and Uganda, respectively, which makes only 1% of public expenditure. Unlike these countries, Great Britain, which is a highly developed country, spends approximately $39.00 per capita on traffic safety [2]. However, this problem can be prevented in order to save people's lives if an appropriate preventing strategy is implemented. The basic mission in the field of traffic safety is to decrease the fatality rate, injury rate and economic losses caused by traffic accidents. If these parameters are observed in a long period it is possible to identify their changes. Therefore the success of the activities done so far can be analyzed and further activities can be properly planned. Competent analyses should be done permanently, while the analyses should be reported periodically depending on the problem (each year, every five years).

2. Methodological approach to the traffic safety analysis of a certain area

Previous research dealing with evaluation of the risk and safety level can be divided into four chronological groups [3]: 1) establishing the interactivity between motorization level, traffic risk and public risk, 2) establishing interactivity between the trend of motorization level, traffic risk and safety risk, 3) integration of many variables in the risk evaluation and safety level, 4) connection between production, good practice and strategic evaluation of traffic safety. In the project [4] numerous indicators were identified but the following ones were suggested: the number and proportion of the fatalities and injured people in crashes in which at least one of the road users was under the influence of alcohol, arithmetical mean value and standard speed deviation, speed exceeding according to vehicle category, use of safety belts, use of the helmets by motorcycle drivers, percentage of use of headlights during the daylight, the age of the vehicle fleet, the structure of vehicle fleet, the evaluation of the roads by a method (*EURORAP* and so on) for all road categories, the percentage of the care for the injured in a defined period. Zhang et al. (2010) used the following indicators to evaluate the safety: traffic risk (the number of fatalities compared to the number of motor vehicles and compared to the number of passenger cars); public risk (the number of fatalities compared to the population); ratio between the number of fatalities and gross national income (*GNI*); identification and comparison of the trend of some analyzed indicators.

On the other hand, Wegman et al. (2010) suggested that the traffic safety of the countries should be compared by a certain relationship of fatalities (the ratio between the number of people who died in car accidents and total population - public risk). This kind of risk definition and safety evaluation has a disadvantage because it does not consider the motorization level. The indicator which is more frequently used is the dynamic traffic risk because it gives better results.

Most countries do not have data on the kilometers travelled, so the indicator presenting the relationship between the fatalities number and number of motor vehicles (traffic risk) can be applied. Today the model is being developed in order to identify the Traffic safety Development Index (*RSDI*) [3]. Out of numerous potential indicators of traffic safety it is necessary to identify the ones which would present the current development of traffic safety, which includes determination of the state of traffic safety and determination of the risk of accident victims, too.

To obtain expected results from the analysis of traffic safety, it is necessary to define its elementary content and methodological approach to such an analysis. The analysis of safety state at a certain area should include the contents illustrated in figure 1 [5]. The following sections of the paper analyze systematically the safety state at a certain area whereas the analysis is largely based on the suggested model in those parts which have related relevant and available data.

2.1. Traffic development in the municipality of Trstenik from 2004 to 2009

The research presented in this paper included the territory of the Trstenik municipality through the analysis of tendencies of the basic indicators of traffic safety of a certain area. The fundamental aim of the paper is to consider the changes of basic indicators of traffic safety and identification of changes trends, as well as comparative analysis with reference areas. The research includes the period from 2004 to 2009 (hereinafter the period) where the data are structured according to the years of the period. Key limitations in the paper are reflected in the terms of data completion because a certain number of data needed for the analysis were not recorded and were unavailable.

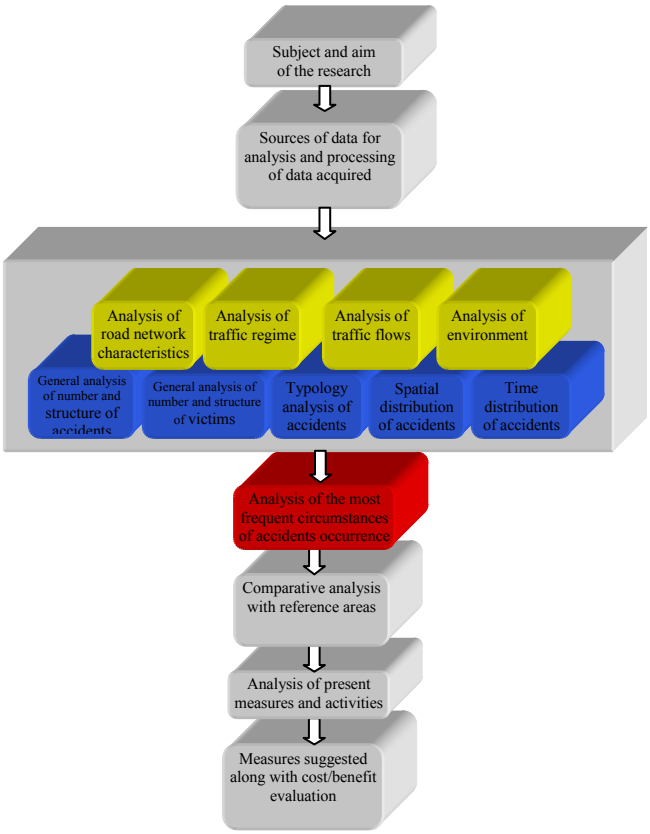

Fig. 1. *Methodological approach to the analysis of traffic safety of the area*

The municipality of Trstenik is a middle developed municipality in Serbia. Most of its territory is located in the valley of the river Zapadna Morava, with the altitude of about 171m and its area is 448 km^2 including 51 settlements. In the recent years agriculture has played an important role in entire economic structure of the municipality. 65% of the total territory is agricultural land which is mostly a private property (95%).

The analysis of traffic development in the Trstenik municipality within the period was done by three basic indicators: development of motorization level, number of drivers, and development of road network (figs. 2 and 3). The Trstenik municipality had 54.654 inhabitants in 2001. The number of inhabitants in the period was observed on the basis of statistical data on natural increase and migration [7]. There was a slight decrease of the number of inhabitants, (fig.2) which is caused by the migration due to bad economic conditions in the period, especially due to poor business activities of the local industry (the factory ''Prva Petoletka'', etc.). The levels of motorization expressed in the number of inhabitants per passenger car and per motor vehicle were compared and it was noticed that the motorization level expressed in the number of inhabitants per passenger car was increased faster than the motorization level expressed in the number of inhabitants per motor vehicle. It can be concluded, therefore, that people bought more passenger cars than other motor vehicles. The increase of the motorization level expressed in the number of inhabitants per motor vehicle was generally related to the increase of lorries and tractors (fig. 2). The number of drivers of all ages was increased for about 16%. The number of drivers older than 65 was increased for about 73%, the number of drivers aged 18-25 was increased for about 43%, while the number of drivers aged 35-65 was increased for only 5% in comparison to the year 2004. Most of drivers were the ones aged 35-65 and their proportion was decreased for about 9%, while the proportions of drivers aged 25-35 and 18-25 were decreased for 2% and 24%, respectively. Although the number of drivers older than 65 was increased most, their proportion was only 3%. The dominance of this group of drivers (older than 65) was caused by overflowing of one age category into another.

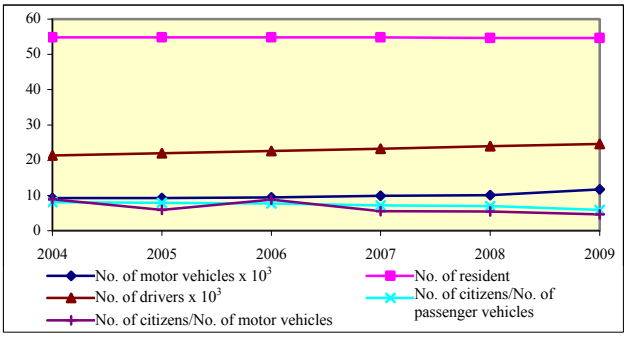

Fig. *2. Trend related to the number of drivers, inhabitants and motorization level in the period*

The total road network of the Trstenik municipality is 231.05 km, of which 19.1 km is a motorway (M-5) which is entirely asphalted and goes around Trstenik, four regional roads whose total length is 70.5 km (63.30 km of it are asphalted, 7.17 km are not asphalted). Local roads include 31 roads whose entire length is 148.5 km (111.5 km are asphalted while 29.98 km are not asphalted). Whole city network has modern carriageway whose total length is about 15km. An average street width is about 6.5m. These data were compared with the data on development of road network in Central Serbia and Serbia in order to evaluate the density of road network (fig. 3). The average density of road network in the Trstenik municipality is 0.516 km/km^2

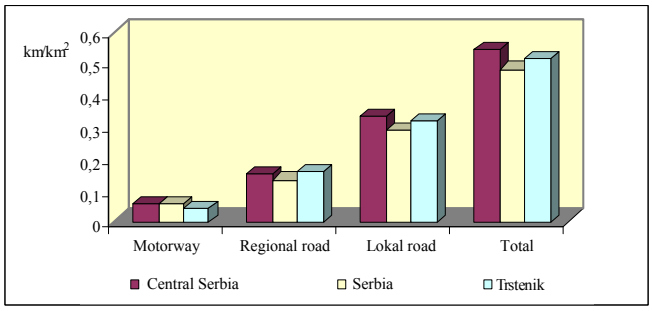

Fig. *3. Indicator of road network density in the Trstenik municipality*

2.2. Safety indicators in the Trstenik municipality from 2004 to 2009

This section includes the entire number of accidents in the period with special reference to the accidents fatalities. Based on the analyzed data in the period, there were 635 traffic accidents, of which 351 accidents fatalities (which makes 55.3% of total accidents) and 284 damage-only accidents (which makes 44.7% of total accidents) [6]. The analysis of these data according to the years shows that the total number of accidents tends to increase slightly in comparison to the starting year 2004, and it is rather disturbing that from 2006 the number of accidents with fatalities was bigger than the number of damage-only accidents (fig.4). The consequences of traffic accidents accompany this trend, too (fig.5). Total of 512 people were the victims in the accidents which happened in the period, of which 313 had minor injuries, 165 were seriously injured and 34 people died. There were 202 passengers, 199 drivers, 21 cyclists and 90 pedestrians. It is particularly worrying that the toll number did not decrease and its mean value was about 85 people a year. The analysis shows that the most endangered categories of road users were passengers, drivers, pedestrians, motorcycle drivers, bicyclists, and tractor drivers, respectively (fig.6). The passengers had relatively the smallest influence on the occurrence of traffic accidents, but on the other hand they were the most endangered category of all road users. The analysis of the accident victims according to the age showed that there were the most drivers and passengers aged 18-25, while the pedestrians involved were older.

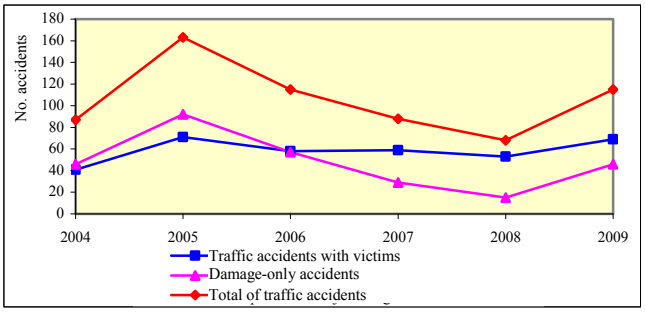

***Fig**. 4. Trend of the accident types according to the years in the period*

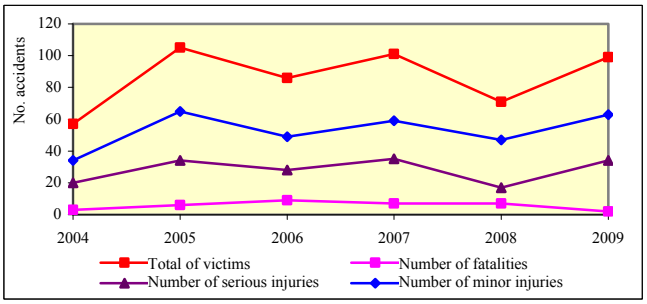

***Fig**. 5. Trend of the severity of consequences according to the years in the period*

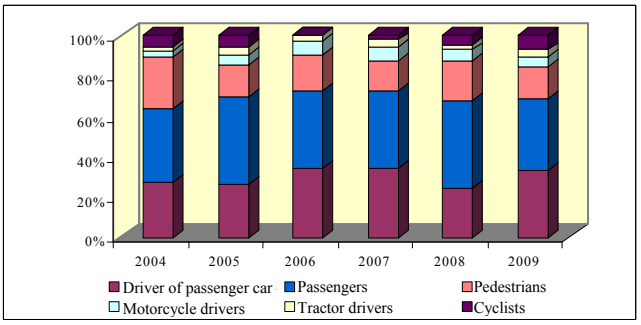

***Fig**. 6. Percentage of different road users categories within the total number of accidents with victims*

2.3. Typology analysis of traffic accidents

Typological analysis shows that the commonest type of accidents in the period was the head-on collision (fig. 7).

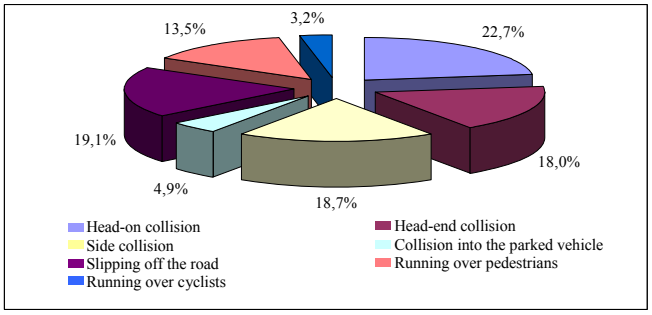

***Fig**. 7. Percentage of circumstances in the total accidents*

By analyzing the accidents with victims in the period it is conclusive that a special attention should be paid to the following types of accidents: slipping off the road, head-on collision, and running over the pedestrians (fig. 8). The analysis of consequences shows that the most persons suffered minor injuries during slipping off the road, whereas the most persons had serious injuries and died during head-on collisions. It can be concluded that the severity of consequences was related to the complexity of driving activity and the speed of vehicle.

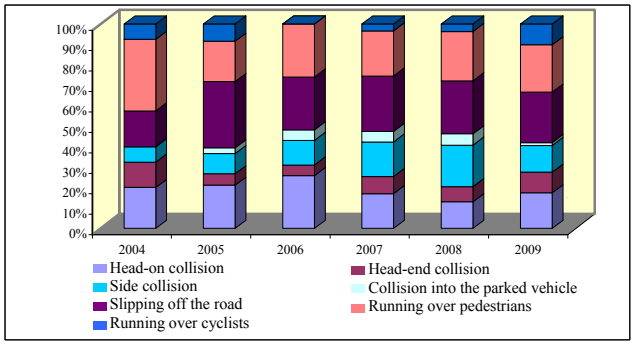

***Fig**. 8. Accidents types within the total traffic accidents*

2.4. Analysis of the causes of traffic accidents

The analysis of causes of traffic accidents is based on the analysis of the errors made by road users because these errors are stated in the Traffic Accident Form as the causes of accidents. In the period the improper speed was the ''cause'' of 219 accidents, i.e. that made 34.5% of all traffic accidents (fig. 9). The analysis of data shows that the most people were victims in those accidents in which the dominant error was improper speed. Due to this error 130 people suffered minor injuries (41.5% of all people who had minor injuries), 68 people suffered serious injuries (41.2% of all people who suffered serious injuries), and 19 people died (55.9% of all dead people). The speed as a cause of the accident is rather undefined; there are some statements that speed cannot be direct cause of accidents. On the other hand there are some statements that speed is directly or indirectly present in all accidents because it can be claimed that in almost all accidents the speed not adjusted to the road conditions, weather conditions and traffic conditions contributes to the occurrence of the accident, which is largely abused by the officers during investigation procedure.

Technical failure of the vehicle and phychophysical state of driver are the last in the list of ''causes'' of traffic accidents. The characteristics and state of the road were not at all registered as the ''cause'' of accidents in the period. This means that all circumstances which led to the occurrence of accidents were not considered during investigation. The fact is that only the most convenient circumstances were considered in order to find the cause of accidents.

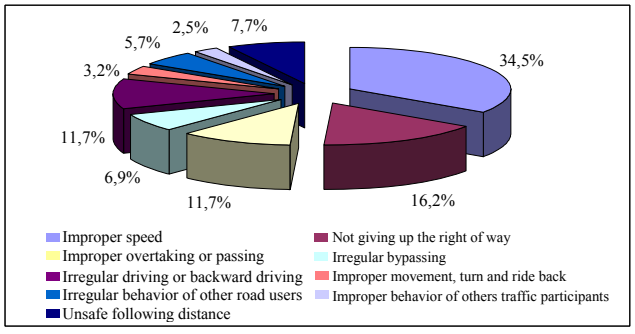

***Fig**. 9. Specific types of errors within the total of accidents*

Based on the trend of errors which resulted in traffic accidents with victims in the period it can be noticed that the speed was dominant error and that it was a constant element of total errors in the period (fig. 10). It can be noticed that the more severe consequences were, the bigger was the influence of the speed on the consequences, so the fatalities were caused mostly by excessive speed. Therefore the speed which was not adjusted to the road conditions and traffic conditions was the greatest threat to road users, so the problem must be solved with great care. Also it should be mentioned that improper speed was stated as the main cause of accidents, but it certainly was not the only cause. However, the fact is that improper speed had a huge influence on occurrence and result of accidents.

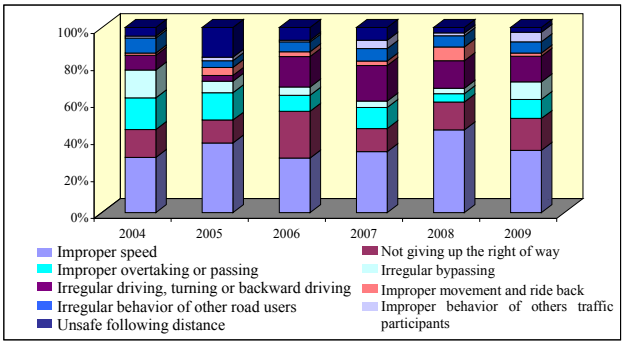

***Fig**. 10. Percentage of certain types of errors in the accidents with victims*

2.5. Spatial analysis of accidents

This analysis deals with the places where accidents with victims happened. In the period analyzed there were 284 accidents which happened out of settlements (80.91%), and 67 accidents which happened within the settlements (19.09%) (fig. 11). Out of all accidents which happened out of settlements 117 accidents happened on the motorway, 85 accidents happened on the local roads, 82 accidents happened on the regional roads. Out of all accidents which happened within the settlements 43 accidents happened on the city streets, and 24 accidents happened on the city intersections. Out of all injured people 430 people were injured out of settlements, whereas 84 people were injured within the settlements (fig.12). It is noticeable that most accidents happened on the motorway. The problems related to this type of roads are multiple. In the Trstenik municipality the motorway mostly goes through the settlements which are directed to it. Therefore there was a significant mixture of local traffic and transit traffic both of which have different regimes. Pedestrian flows made an extra problem because they used one part of this motorway since there were no pedestrian pavements. This motorway was connected to the city street network by two intersections; one of them met technical and functional requirements of safe junction to the motorway, while the other one did not meet technical requirements thus being a great danger.

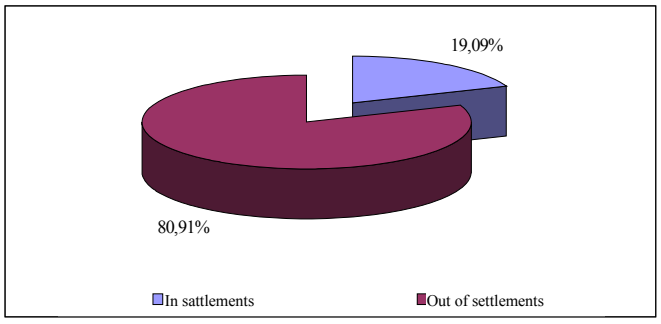

***Fig**. 11. Percentage of accidents distribution according to the place of their occurrence*

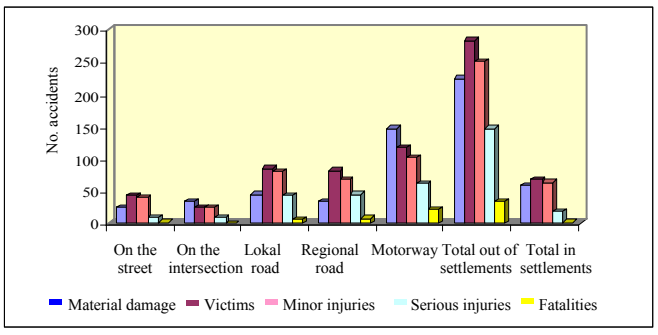

***Fig**. 12. Spatial distribution of accidents in the whole period*

2.6. Temporal distribution of accidents

Temporal distribution of accidents was done through three parallel analyses: the analyses of accidents according to the months, days and hours. Each analysis had equal significance in order to undertake actions and measures timely [8]. The analysis showed that the most critical months were from June to October (fig.13). The accidents started to grow from June and the most of them happened in October.

Distribution of accidents with victims had the similar distribution as the total accidents but they reached the maximum in September. In all distributions the number of accidents and victims reduces after October until February when their number again started to increase. Distribution of dead people is the one which was not similar with other distributions because the number of dead people was almost equal during the whole year with a slight decrease in winter (fig.13). The cause of this distribution was probably bigger agricultural activity in this period since the intensity of agricultural operations was the smallest in winter months, so the road users' activities were reduced just like the number of accidents.

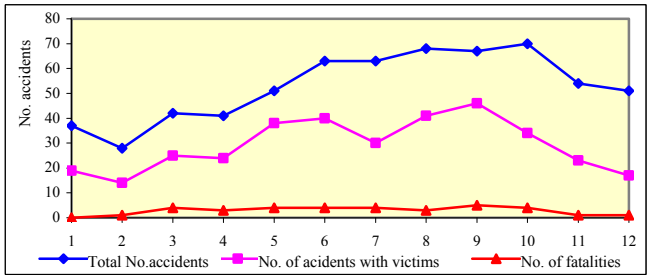

***Fig**. 13. Temporal distribution of accidents according to months*

The analyses of total accidents, accidents with victims, and the number of fatalities according to the days of the week showed which days were the most critical. The most critical days were Wednesdays, Fridays and Saturdays because during these days the number of accidents was bigger than the mean value of accidents happening in other days of the week (fig.14).

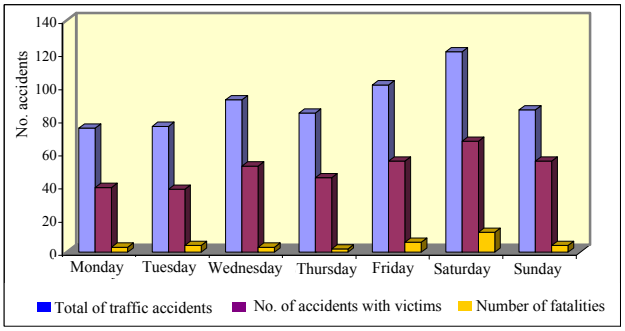

***Fig**. 14. Temporal distribution of accidents according to days*

We can notice the same distribution when distribution of accidents with victims was analyzed. It implies that the biggest number of accidents which happened on Wednesdays, Fridays and Saturdays were the accidents with victims. Upon comparison of all distributions it was noticed that the most critical day was Saturday. The most accidents happened on Saturdays, and the most of them were the accidents with victims and the most road users were injured. As mentioned above, the Trstenik municipality is an agricultural area and the temporal distribution according to months showed that the most accidents happened exactly in the months with increased agricultural activity. Thus the distribution according to days was logic. Namely, agriculture is not the dominant profession of Trstenik's citizens; it is their secondary activity, so most of these activities were done at weekends. The analysis of accidents according to the hours showed the hours of the day in which higher number of accidents happened. Most accidents happened from 11a.m. to 4p.m. and about 7p.m. (fig.15). In these hours the traffic

was more congested and the activities of road users were increased. The activities lasted until 9 o'clock in the evening and after that period the number of accidents declined. The distribution of the number of accidents with victims was nearly the same, but the maximum of these accidents happened from 3p.m. to 8 o'clock in the evening. The accidents with fatalities were relatively equally distributed during the whole day but there was an increase from 10a.m. to 11a.m. This increase was most probably related to increased activities in the city zone, especially to pedestrian activities who were mostly the victims. However, the fact is that the activities were gradually reduced in the evening hours as well as the total of accidents, and the fact is that the number of fatalities kept a mean value during this period. So it can be concluded that much more road users were injured during this period than in other periods of the day.

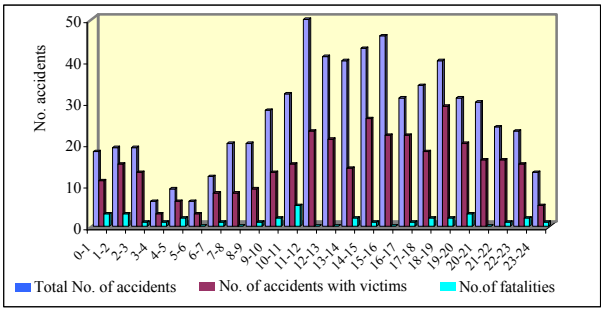

***Fig.** 15. Temporal distribution of accidents according to the hours*

According to this fact, such a distribution was not caused only by agricultural activities but by the young people as well who went out at weekends. It is well known that most young people go out during weekends, which makes traffic more congested and makes more accidents happen in this period of the week and day. If we associate this with the fact that the victims of accidents were mostly people aged 18-25 then it is obvious why this maximum went to the late evening hours. Although there was a decline of total accidents in late afternoon hours, there was an increase of accidents with victims, which results in damage-only accidents to be replaced with fatal accidents.

3. Relative safety indicators

Previous data are absolute indicators of traffic safety for the territory of Trstenik municipality and they do not allow us to compare these data with other municipalities, the state in the country and other countries. To determine the real state of traffic safety the relative indicators of traffic safety were introduced and they were the base of the comparison. The state of traffic safety in the Trstenik municipality was done by two indicators, i.e. public risk and traffic risk and by their comparative analysis with the state in the country and surrounding countries (figs. 16 and 17). These indicators were chosen because they are generally accepted and standardized parameters of evaluation of traffic safety at the global level (see section 2). The data on dynamic traffic risk cannot be analyzed yet, because the data about kilometers travelled are not registered in Serbia unlike other members of OECD [9, 10]. Basic limitations in the comparative analysis in the period observed were data completion, because certain data needed for analysis were not available.

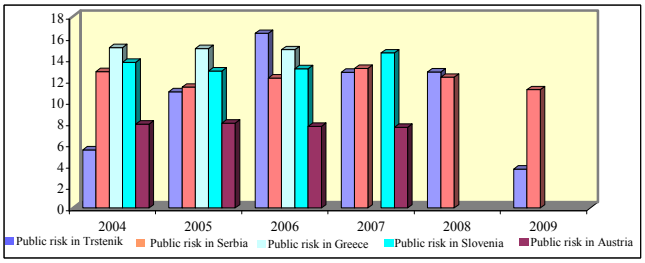

***Fig.** 16. Comparative analysis of public risk of the analyzed area*

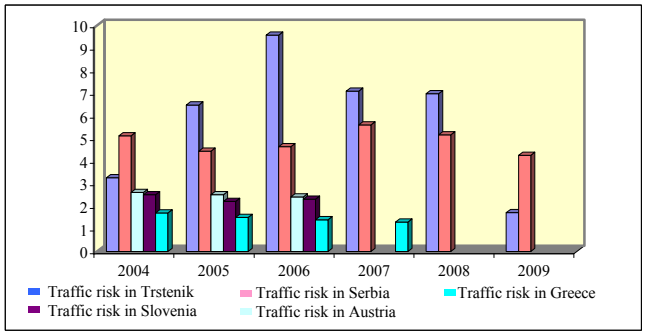

***Fig.** 17. Comparative analysis of traffic risk of the analyzed area*

The comparative analysis showed that the Trstenik municipality tended to decrease public and traffic risk in last three years of the period. However the traffic risk in Trstenik was extremely high in comparison to other reference areas. Relatively worse state of traffic safety, on the basis of these indicators, in comparison to other countries, can be explained by neglecting the problem in the period. Traffic safety has not yet reached the level in the society which would make it one of the priorities at all levels of society. Apart from that, there was a series of other factors such as organizational, technological, economic and other ones which affected the fact, but they should be treated as a special subject of other research.

4. Discussion

The analysis of motorization level clearly shows that even bigger motorization level can be expected in the Trstenik municipality in the further period, since there was a constant increase of registered vehicles of almost all categories in the period observed. This tendency will be most probably carried on in the future so we can expect the increase of number of vehicles.

The number of drivers was also increased in the period and it has a tendency to keep on increasing in the future. The increase of all categories of drivers can be expected but the drivers of passenger vehicles will be dominant. The biggest increase of the number of drivers aged 18-25 is expected and this category of drivers is the most endangered in terms of the road users in traffic accidents. The fact is that in the near future both the number of drivers and vehicles is expected to increase and this fact results in increased intensity and volume of traffic on the road network, which leads to insufficient traffic capacity of the road network to service such a traffic volume. In the period the road as a cause of the car accident was not registered at all, so we got the wrong impression that the road network was at a satisfactory level, which was not the case. This problem is very complex because it involves huge financial resources which will be invested in building new roads and reconstructing the old ones. However, if all social subjects are clearly defined and if all road users are coordinated within the chain, the problems of today's increased traffic can be successfully solved and overcome by financial resources. Also maximum benefit which modern traffic implies nowadays will be obtained this way.

The analysis of traffic safety presented in this paper gives a real picture of the traffic state in the Trstenik municipality and its problems in the period from 2004 to 2009. The traffic safety in the Trstenik municipality in the period was not satisfactory, especially in the terms of traffic risk. It is mainly the consequence of poor traffic culture, bad relationship towards traffic equipment and roads, unconscientious work of some services and technical failure of the vehicles running in the traffic. All these elements above are the elements which provide regular, efficient and safe traffic. Some concrete solutions are suggested in these elements in order to raise the level of traffic safety.

It is necessary to establish as soon as possible the municipal Council for Traffic Safety in order to coordinate the work of all services and organizations responsible for traffic safety or for traffic in general, and to establish competent commissions which will analyze certain traffic phenomena which may make all traffic

elements better or worse. The authorities of the Trstenik municipality must adopt a strategic act on technical regulation of traffic in the Trstenik municipality regarding not only new system but the exploited system as well.

The strategic provision on technical regulation must have appropriate form and content which must include general provisions, information service (registry of traffic system supported by GIS technology), and measures of technical traffic regulation (general regime of dynamic traffic, the regime of lorries and supply of various facilities, the regimes of transit remote, bicycle and stationary traffic, as well as the regime of pedestrian traffic).

Direct influence on traffic road users can be achieved by specific actions and campaigns which must be permanently conducted through mass media, especially during the months in which the number of traffic accidents is increased [11]. The current campaigns are mostly directed to the problem of technical failure and drunken driving (which is the cause of only 6% of accidents) whereas the other causes are not treated at all. A special attention should be paid to the training and campaigns which would be aimed at the most endangered categories of road users.

The hypothesis presented in the paper is that the biggest problem is the activities related to agriculture and this hypothesis should be covered by some actions which would minimize the problem. Also this sort of road users must have the positive attitude toward proper behavior in the traffic. A special attention should be directed to the motorway sections of the road because transit, local and pedestrian flows are mixed and because the drivers and pedestrians in this area have fallen into a habit when doing some traffic activities and they have rooted opinion that everybody else is familiar with the local customs.

A difficult economic situation and insufficient financial resources are a big problem. One of the possible solutions is to use the collected fines for financing the equipment and projects which would increase the local level of traffic safety.

5. Conclusion

It is necessary to define the basic content and methods of the analyses of the state of traffic safety so that they have expected effects. It should guarantee comprehensiveness, correctness and objectivity, and it should also make analyses comparative and useful in further research work. Social and economic interests can also obstruct the operation of this system. Safety measures are mainly restrictive and thus socially unpopular. When the solution is unpopular, the research results rarely become the safety measures. At the present time the best way to increase traffic safety and to conduct necessary measures are statistical data on traffic accidents. The fact that the accidents already happened put the researchers at a serious disadvantage.

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