Traffic Accident Occurrence, Its Prediction and Causes

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Abstract. A traffic accident represents a stochastic negative event in traffic on road communication network. Sufficiently detailed analysis of traffic accidents and the implementation of some suitable measurements can be helpful to prevent an occurrence of accidents at selected locations where traffic accidents' occurrence is more frequent. It is also important to analyses and understand the environment and events that occurred before and during the accident. The emergence of a traffic accident is always caused by three main factors: a driver, a vehicle and a road communication. The range of causes of traffic accidents is wide, but most accidents are caused by driver inappropriate behavior. Several years, the methods have been developing for traffic accidents prediction. A different view of issue of traffic accidents gave rise to several methods. These methods generally define the probable number of traffic accidents or the number of injured, killed persons at certain section of the road or in a certain area.

Keywords: Traffic accident · Cause of a traffic accident · Probability · Black spots

1 Introduction

Every driving is connected with specific rate of risk. A risk can be defined as some uncertainty or rate of probability that traffic conditions could result into a dangerous situation. A traffic accident occurrence we can understand as a mixture of various consecutive events. Always we should calculate and deal with what can happen. Human failures is predominantly cited as a primary cause of traffic accidents.

Today vehicles are equipped with different safety systems. The main goal of vehicle safety is protection of lives of road users. Traffic safety is a serious traffic, social and economic issue.

2 Traffic Accident in Road Transport

The balance of three factors – driver, vehicle and environment is disrupting when traffic accident occur. According to recorded data most often traffic accident causes in Slovakia including breach of driver's obligations and road users' obligations, unlicensed speed, wrong way of driving, incorrect overtaking and turning. Based on long term

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analyses it has been found out that driver behavior has an important effect to traffic accident occurrence. The disruption of driver's obligations represents an average 43,1% of the total number of causes in Slovakia in last 5 years (Fig. 1). You can see on the Fig. 1 that the number of traffic accidents per year in Slovakia is approximately the same. However, it is obvious that rising of the number of accidents increases also the human factor effect in accidents. In addition to the behavior and psychological state of driver, the technical state and communications operating conditions (weather conditions) also affect the occurrence of traffic accident.

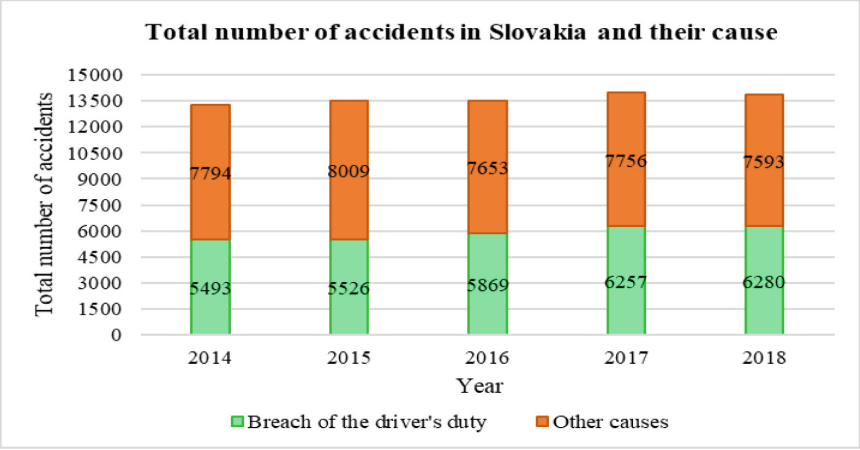

Fig. 1. Total number of accidents in Slovakia and their main cause [13]

Although the number of fatal traffic accidents is decreasing in Europe, the European Union released a White paper – Roadmap to a Single European Transport area. One of the main goals of this paper is to decrease the number of fatal traffic accident in road transport to 2050 to zero. In line with this objective the EU is working to decrease also the number of accidents at all to halve by 2020 [1, 2, 12, 13].

2.1 Traffic Accident Indicators

The need of comparison of traffic accident rate from different point of view (time and location) gave rise several additional criteria. In general, we called these criteria as criteria of traffic accident rate and they serve to the more detailed evaluation and comparison of traffic accident rate.

Criterion of traffic accident density represents the number of accidents per length unit of communication. It is used most to traffic safety evaluation of main roads when it is possible to compare each section to another and set the riskiest one.

$$H = \frac{N}{t * L} \tag{1}$$

Where:

H – density of accident [TA/(km.year)]
N – a number of traffic accidents in year [TA]
L – a length of a section [km]
t – a time period [year]

Criterion of relative accident rate is the most used criterion to safety evaluation of road communications. Its value represents mainly a probability of traffic accident occurrence on the chosen section of communication which is related to driving performance [4, 5, 7].

$$R = \frac{N * 10^6}{365 * RPDI * t * L} \tag{2}$$

Where:

R – relative accident rate [TA/(10^6veh.km)]
N – a number of traffic accidents [TA]
RPDI – an average daily intensity per year [TA/24 h]
L – a length of a section [km]
t – a time period [years]

In the project Pilot4Safety were used three mutually independent parameters to identify road sections with high traffic accident rate.

Critical accident rate (CAR) - to the number of accidents per million of vehicle-kilometers traveled per year.

Relatiuve severity index (RSI) - compares accident costs based on standardized statistical valuation of individual types of accidents in individual years (the cost of fatal accidents, severe injuries, light injuries and average material damage without injury) [5, 16].

3 An Analysis and a Probability of Traffic Accident Occurrence

We can make analysis of traffic accident in two ways:

- **Simple analysis –** serves to obtain a basic idea about accident location. We investigate mostly time occurrences of traffic accidents, weather conditions, accident locations, types and causes of accidents.
- **Detailed analysis –** if it is not possible to obtain a certain reason of accidents occurrence, it is necessary to make more detailed investigation. The spatial route guidance is thoroughly examined, the type and quality of road surface, transport load and others [1, 3, 10].

When traffic safety is evaluating by means of statistics, there is one disadvantage that the evaluated accidents have already happened. Therefore, there is a long term process of new methods evolution which would be able to prognoses traffic accidents

and evaluate safety on the chosen part of communication before an accident will occur. A different point of view to traffic accident prognosis allows to develop several methods. These methods evaluate safety or predict a number of traffic accidents, number of fatalities and relative or absolute accident rate per the chosen time period [6, 14].

3.1 Prediction Models of a Number of Traffic Accidents

Unified methodology of traffic accident prediction does not exist. Every model is useful only for one specified area. There are several variations of a general relation for accident prediction from simple ones where the risk factor is intensity of vehicles to complex models considering a big amount of crash coefficients.

$$E(k) = \alpha * L^{b1} * RPDI^{b2} \tag{3}$$

Where:

E(k) is an expected number of traffic accidents,
bj represents coefficients which were obtained for model calibration of specific area.

The biggest issue when model formulating is to get correct values of parameters which would be used for specific area. Of course, other models are developing which are based on linear regressive analysis or Poisson distribution [9, 15].

3.2 Bayes Model

This model can be used to estimate a probability of traffic accident occurrence. Classic statistics determines a probability of some event based on known facts from past but when this statistic cannot be used the Bayesian statistics is an alternative. It is a model which takes into account not only available facts but also dependence between them. Bayes' veto is basic sentence in Bayesian statistic. It is used to updating a probability which are the degree of faith after obtaining new data [15].

3.3 Black Spots

When identifying black spots, the basic principle is that traffic accidents (TA) are not evenly distributed on roads but occur more frequently in certain locations (places and sections) than elsewhere. Therefore, from the view of mathematical statistics, the occurrence of traffic accidents on roads could be considered as infrequent unevenly distributed effects. Their occurrence can therefore be considered as a discreetly changing variable. The distribution of such a probability effect on roads can be exactly described by the Poisson distribution [8, 14].

This probability distribution has random variables that describe the number of phenomena with the following properties:

– if a phenomenon in a given interval (time, space) occurs (does not occur), regardless of what happened elsewhere, or another time,

– for each time point, the probability of the phenomenon is the same in a short time interval (the same is true in the space)
– there is no case that two occurrences occur at exactly one time or at a location in the institution.

The average number of occurrences of the studied phenomenon in a given length section is denoted λ [11].

$$P_{(x)} = \frac{\lambda^x}{x!} * e^{-\lambda} \tag{4}$$

Where [14]:

P(x) – is the cumulative probability of the occurrence of x number of critical TA per year on a selected standard length of the road network in a specific territorial unit in empirical population for chosen confidence level,
m – parameter indicating average mean values (average number of TA) on the road network based on a chosen criteria indicator in a specific territorial unit,
x – calculated critical number of TA per year on the unit of length of the road network with certain probability P in a specific territorial administration unit,
e – base of natural logarithm.

4 Evaluation of Traffic Accident Rate on the Selected Section

For analysis of traffic safety, we have used I. class road I/11 which is a part of road E75. This road connects north and south Europe. The road enters Slovakia through the border crossing Svrčinovec and leads to Žilina in 36,8 km of length. It belongs to roads with very high number of accidents per year.

The riskiest section of road I/11 is between border crossing Svrčinovec (SR - ČR) and Čadca city (Fig. 2). According to police records, the chosen section between kilometre of 407,700 and 410,500 (2,8 km) has the highest occurrence on this I. class road.

Fig. 2. Selected road section of the communication I/11 [own study]

We analysed factors influencing traffic accidents in last 5 years because of better overview of traffic accident rate on the chosen road section. The number of accidents on the whole communication I/11 represents 290 at all. At the given section, the same time was at 72 accidents which represents approximately 25% of the total. It is a communication which connects Slovakia with two countries (CR and PL) and a transit transportation is available. The composition of the traffic flow is approximately 59% are light vehicles and 41% heavy vehicles. There is a junction on this road section and in this case the road was divided into two parts. First part of 1,2 km length and the second one was 1,6 km of length (Fig. 2). The intersection is situated at 408,900 km (A4). The reason why this road section was divided is a change of averaged daily intensity at the intersection. At the first part of the section there were recorded 53 traffic accidents and at the second one there were 17 traffic accidents. At the mentioned junction there were recorded 2 traffic accidents. There is also a railway crossing and a sharp curve in the section (Fig. 3).

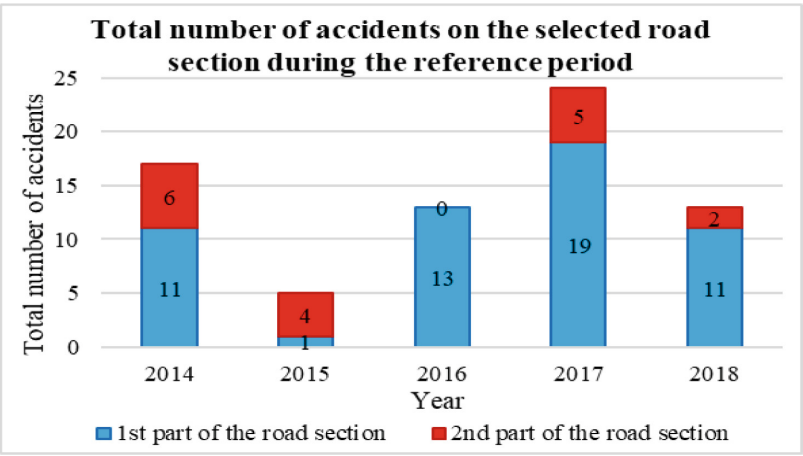

Fig. 3. Total number of accidents on the selected road section [own study]

4.1 The Main Causes and Condition of Traffic Accident

As it is known, the biggest influence to traffic accident occurrence has a human factor. Transport behaviour of a man effects lots of external as well as intern factors. In this case there was a disruption of drivers' obligations mentioned as a main cause of traffic accident. It represents 61% from all causes. Almost every causality of traffic accidents, except weather conditions, were caused by a human failure. At the chosen part of communication there were causes of traffic accidents as follows:

- Disruption of drivers' obligations
- Inappropriate behaviour at the railway crossing
- Breach of road users' duties
- Inappropriate way of driving

– Inappropriate way of driving through an intersection
– Inappropriate overtaking
– Inappropriate turning
– Breach of specific establishments about pedestrians
– Breach of rules of cargo transportation
– Natural force
– Non – observance of distance between two vehicles
– Unsuitable way of driving during winter season.

Their proportion is shown in the Fig. 4. Over 70 traffic accidents have been caused by human factor failures which represents 98,6% and only 1,4% of traffic accidents have been caused by an environment (weather, carriage drive).

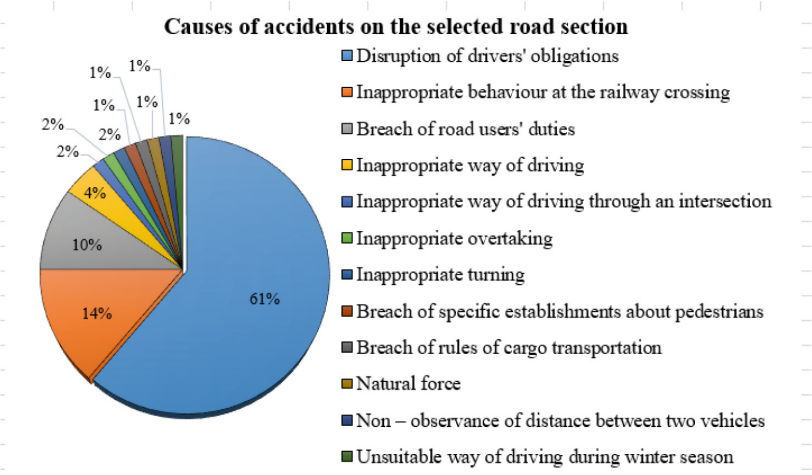

Fig. 4. Main causes of accident on the road section [own study]

Also weather conditions are one of often causes of traffic accidents as well as directional and vertical alignment of route (Fig. 5). Weather conditions which influenced traffic accident rate on the chosen section includes:

– fog,
– rain,
– snowing,
– black ice.

These factors have the biggest impact on increasing traffic accidents occurrence. The highest number of traffic accidents, 89%, was recorded during normal conditions. The rest of TA was influenced mainly by weather which has made operating conditions of transport more difficult. Also directional and vertical alignment of route has an impact on an occurrence of traffic accidents. As you can see in the graphical evaluation, the highest number of traffic accidents – 80%, have caused on the straight section and 17% of TA in curve. On the chosen road section, it is bad outlook behind mentioned curve.

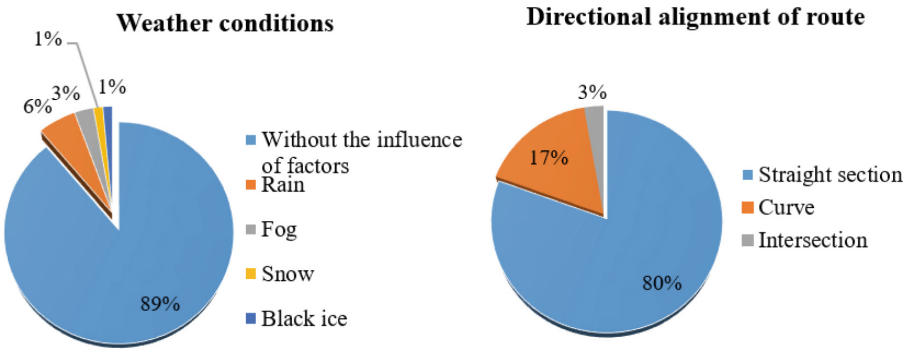

Fig. 5. Influence of weather conditions and directional laying of the roadway on accident [own study]

4.2 Time Occurrence and Culprit of Traffic Accidents

It is also important to find out when during the day a traffic accident happened. Was it day or night as well as in which day the most traffic accidents occurred. The probability of traffic accident is significantly affected by traffic peaks. The following figures show processed values from the records.

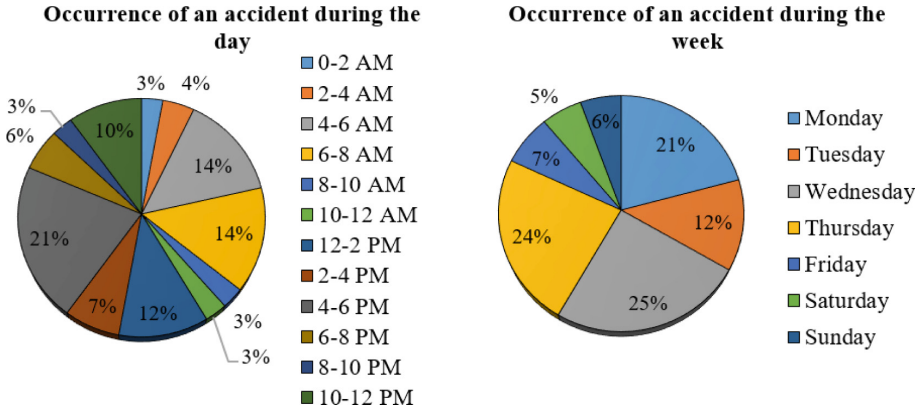

Fig. 6. Occurrence of an accident during the day and week [own study]

As you can see in the Fig. 6, the highest number of TA is recorded during an afternoon from 4 to 6 p.m. It represents 21%. The lowest number of TA was recorded in early morning and from 8 to 12 a.m. The most overloaded day was Wednesday – 25%, then Thursday – 24% and the lowest number was recorded on Saturday – 5%.

Traffic accidents divided according to type of vehicle and culprit you can see in the next figure. It is obvious that drivers of motor vehicles are the most often the cause of traffic accidents – 94%. Then as a culprit are pedestrians and cyclists. In 56% of traffic accidents there were recorded no types of vehicles.

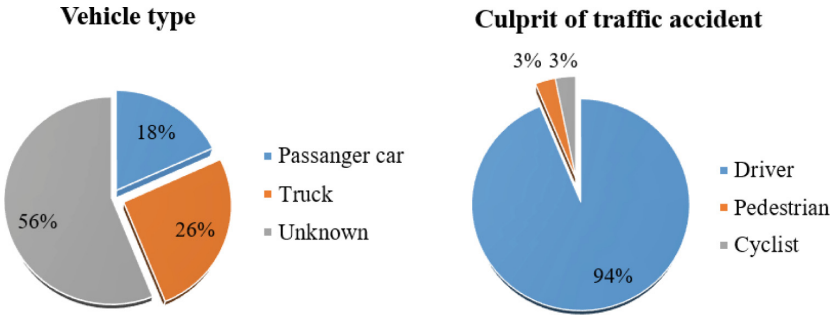

Fig. 7. Vehicke type and person responsible for the TA [own study]

4.3 The Locations of Traffic Accidents on the Chosen Part of a Road Communication

Consequences of traffic accidents on this section are not so serious. In last 5 years there were recorded 4 hard injured people and 4 light injured persons. Material damage achieved 219 470 € at all. The reason of less serious accidents can be a fact that the chosen section is situated in a village and a maximum speed is 50 km/h. Over the last few years, congestions are also part of the daily traffic issues. In the Fig. 7 there are highlighted the places of traffic accidents occurrence for better orientation, because traffic accidents were not spread over the same length each year. The record is created in the system with density of 5 TA per kilometre. The chosen part of road is divided into the same parts with length of 400 m for better processing.

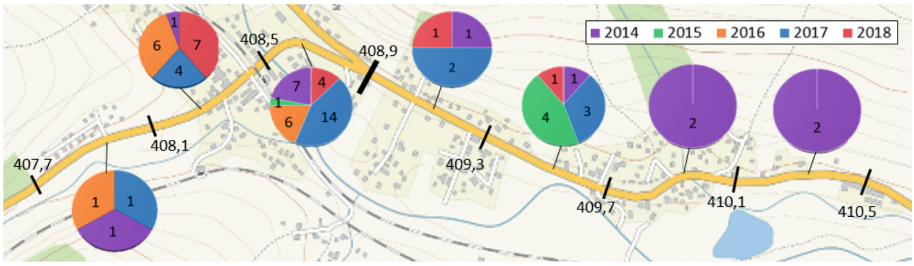

Fig. 8. Total number of accidents on the selected road section during the reference period [own study]

The longest line represents the intersection on the road section. The highest number of traffic accidents was recorded in 2017 (24) and the lowest number was in 2015 (5).

Table 1. Number of TA on a road section with a separation of 400 m [own study]

Road section	2014	2015	2016	2017	2018	Total
407,7-408,1	1	0	1	1	0	3
408,1-408,5	1	0	6	4	7	18
408,5-408,9	7	1	6	14	4	32
Junction (408,9)	2	0	0	0	0	2
408,9-409,3	1	0	0	2	1	4
409,3-409,7	1	4	0	3	1	9
409,7-410,1	2	0	0	0	0	2
410,1,40,5	2	0	0	0	0	2

Figure 8 and Table 1 show that the highest number of traffic accidents was on the section from 408,1 to 408,9 km – 53 TA/1,2 km in 5 years. Riskier section is situated behind the intersection. On this section there is also railway crossing, sharp curve and changing of vertical alignment (Fig. 9).

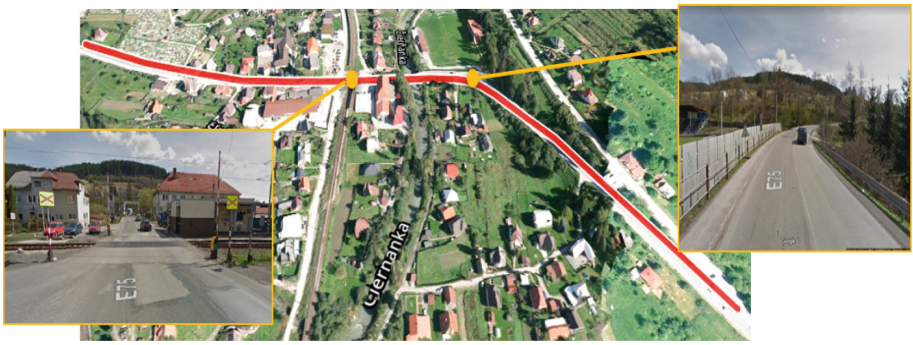

Fig. 9. Road section with the greatest number of accidents per year [17]

4.4 Safety and Traffic Accident Occurrence

Normal (safe) transportation is when all routes to the destination are made without any accidents and danger. To evaluate traffic safety, we mostly use a criterion of relative accident rate (R). Using this criterion, it is possible to set a probability of traffic accident occurrence related to driving performance. The higher the result of this indicator, the higher the risk of an accident. In the following table there are calculated values of this criterion with the same length of sections per year (Table 2).

Table 2. Average daily intensities per year and relative accident rate [own study]

Years	2014		2015		2016		2017		2018	
Road section	RPDI	R	RPDI	R	RPDI	R	RPDI	R	RPDI	R
407,7-408,1	7119	1.0	7972	0.0	8116	0.8	8257	0.8	8465	0.0
408,1-408,5		1.0		0.0		5.1		3.3		5.7
408,5-408,9		6.7		0.9		5.1		11.6		3.2
Junction	10716	0.5	11465	0.0	11637	0.0	11808	0.0	11894	0.0
408,9-409,3		0.6		0.0		0.0		1.2		0.6
409,3-409,7		0.6		2.4		0.0		1.7		0.6
409,7-410,1		1.3		0.0		0.0		0.0		0.0
410,1,40,5		1.3		0.0		0.0		0.0		0.0

R - relative accident rate [TA/(10^6veh.km)]
RPDI - averaged daily intensities per year [veh/24 h]

Final results are possible to compare to each other because a number of traffic accidents is recorded at the same section every year. The most critical section according to final values is from 408,1 to 408,9 for 2017 and 2018.in this case the number of TA achieve values over 3. If values of criterion R is over 1,6 it points to significant lacks of traffic safety. Regarding the intensity of vehicles are increasing the section becomes riskier in the future. The main cause of accidents is railway crossing. Up to 28 traffic accidents happened right at this railway crossing (year 2017–2018).

Theoretically, we assume that the occurrence of traffic accidents is unevenly distributed in this most overloaded section. Then, the distribution of this probability phenomenon can be accurately expressed in Poisson distribution (formula 4). On this section there were recorded 10 traffic accidents in average per year. Using Poisson distribution, it is possible to estimate a probability (P) of traffic accident occurrence on this section (Table 3).

Table 3. Probability (P) of traffic accident occurrence on this section [own study]

Number of TA	P per year	%	P per half year	%
>0	0.9999	99,99	0.9932	99,32
>1	0.9995	99,95	0.9595	95,95
>2	0.9972	99,72	0.8753	87,53
>3	0.9896	98,96	0.7349	73,49
>4	0.9707	97,07	0.5595	55,95
>5	0.9329	93,29	0.3840	38,40
>6	0.8698	86,98	0.2378	23,78
>7	0.7797	77,97	0.1333	13,33
>8	0.6671	66,71	0.0680	6,80
>9	0.5420	54,20	0.0318	3,18
>10	0.4169	41,69	0.0137	1,37

These estimations are made based on recorded data from last few years. The table shows that probability (P) of traffic accidents occurrence of more than 0 TA per year is almost 100% and for half year it is 99,32%. However, an assumption that more than 10 TA occur, probability decreases to 41,7% per year and 1,37% per half year. As a number of traffic accidents increases, the probability of their occurrence decreases. It is just theoretical calculation. This chosen section could be considered as critical regarding the number of accidents on relative short distance.

5 Decreasing Accident Rate on Selected Road Section

On this black spot a TA causes a congestion in both directions. The congestion is several kilometers long, reaching to Čadca or Czech Republic (CZ). The biggest problem occurs during peak traffic. A long column may cause collapse in Čadca. Decreasing accident rate on this section could be solved by completing highway D3 (Fig. 10).

Fig. 10. Highway D3 [17]

Transit transportation will be transferred to highway and our chosen section would by less loaded. A part of vehicles could lead through an intersection Svrčinovec to Czech Republic and other vehicles continue to Poland. Vehicles' intensity on this section would be reduced by approximately 40%. The section of highway between an intersection of Svrčinovec – Poland is already in operation (green colour). Currently the section Svrčinovec – Čadca is in construction. In this case every truck directing to Poland and Czech Republic passing through this accidental section.

6 Conclusion

Traffic accident rate on roads, except serious impacts on safety, represents an important criterion of road conditions level, traffic conditions and quality of road maintenance. Statistics about traffic accidents is basic recourse to finding causes of their occurrence. Based on these data a list of accidental locations is created every year. The goal of this paper was an analysis of traffic accidents on the selected road section. The first step was to determine a causes, time and road conditions of traffic accidents occurrence.

The analysis shows that the main cause of traffic accidents is disruption of drivers' obligations. On the chosen section there are mostly accidents with consequences of material damage. Accidents occur mainly at the railway crossing and in an unclear curve. Next step was to estimate a probability of traffic accident occurrence on this section with using Poisson distribution. We can assume that by improving traffic conditions on the road the number of accidents can be reduced. The possibility of improving the traffic situation is the highway D3. The majority of vehicles (mainly trucks) would be redirected to highway in Čadca. This would reduce the intensity of vehicles passing through the risk area. Then it can be assumed improvement in the traffic situation. However, the biggest impact on traffic accident rate has a human factor. Therefore, every road user can contribute to better safety on our roads by responsible approach to each other.

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