Selected Issues of Transport Safety

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This article is focused on two possibilities of perception of transport safety and transport systems. It describes basic characteristics and elements of road safety in the Czech Republic, and differences of safety in rail transport are also remembered. The article discusses traffic accidents as an indicator of road safety. The paper is created with examples of selection and processing of data transport systems, for road and rail transport of the Czech Republic.

Keywords: Transport systems, safety and security, traffic accidents, road, transport performance, railway track, railroad track, regression, correlation.

1. INTRODUCTION

The basic requirement for any system is its flawless operation under all conditions. In technical systems this requirement is increasingly implemented by means of using technically more advanced and reliable equipment. However, this does not diminish the role of a person on whose management it depends, and also on the safe operation of systems. In transport systems strong emphasis must be placed especially on security. Safe and reliable transportation determines the viability of the entire company.

2. SAFETY AND SECURITY OF TRANSPORT SYSTEMS

Transport systems of all countries are profiled by complex action of many internal and external factors. Requirements for transport are an expression of economic, social, political, cultural, demographic and other needs and interests, which are often mutually contradictory. Taking into account the specificities of other transports as sectors of the economy, it is clear that the security of transport systems individually and as a whole is an existential prerequisite for correct functioning of the sector. At the same time, it determines the right level of performance in virtually all other sectors of society, economy and social priority area in its entirety.

Individual transport systems must therefore have a clearly defined position in the transport system of the state. This position is determined by the possibilities and advantages to meet specific travel requirements, ensuring at the same time maximum quality. However the quality of the transport system is measured by a variety of indicators, including safety.

The perception of transport safety and transport systems gradually evolved and developed into two basic levels. Because the crucial element of any transport system is its technical base (including transport infrastructure, transport equipment and vehicles - mobile devices), also its safety is primarily associated with the technical side. These observations are more or less on the internal state, which is dependent on three basic components: [1]

- Human factors in the implementation of transport, extend actively (e.g. crew transport vehicle) or passively (e.g. random walker)
- Vehicles, which also helps to create a security environment actively (takes or helps to meet the obligations of man – e.g. autopilot) or passively (technical equipment to reduce the negative effects on humans during accidents and immediately after their creation)
- Environment, which includes, in addition to geographical and meteorological conditions

and transport facilities and buildings, information and communication devices.

This "technical safety" is referred to in English as "safety". The second level of transport security is an expression of the ability to reduce or eliminate risks to a transport system as a whole, both from inside and from outside the system. It is therefore a kind of "safe, secure" transport system, expressed by an English term "security". This "security" includes resistance of transport system associated with crisis phenomena resulting not only by natural causes, but also very serious and extensive anthropological causes. The given division does not mean that a breach of "technical safety" cannot be the cause of the phenomenon of crisis on a large scale, typical of large-scale natural disasters or violent crimes.

3. SAFETY OF ROAD TRANSPORT SYSTEM OF THE CZECH REPUBLIC

Road transport system in the Czech Republic is historically one of the most developed ones. This is evidenced by, among others, the following actual data [2]:

- Density of the road network (roads and highways) is 0.707 km per 1 km^2 (with the inclusion of local roads is up to 1,657 km per 1 km^2)
- A total of 6,866 million of motor vehicles (of which 5,115 million cars) were registered in 2015
- The achieved transport performance was in the amount of 79.70 kilometres in passenger transport and 74.59 tonne-kilometres of freight transport in road transport in 2015.

Due to the position of road transport system in the Czech Republic, constant attention is paid to safety. A highly developed individual car transport leads to the active involvement of a wide range of professional organizations and components of the system security, along with the majority of the population. Schematic representation of the system of road safety can be seen in Figure 1.

One of the key indicators of the state and development of the road safety, is the number of accidents and their consequences. Simple statistical numbers in these categories do not give a comprehensive picture of the structure and causes of traffic accidents. It is precisely that these data are the basis for the adoption of the necessary prevention measures. The basic indicators monitored include information about the origin of accidents:

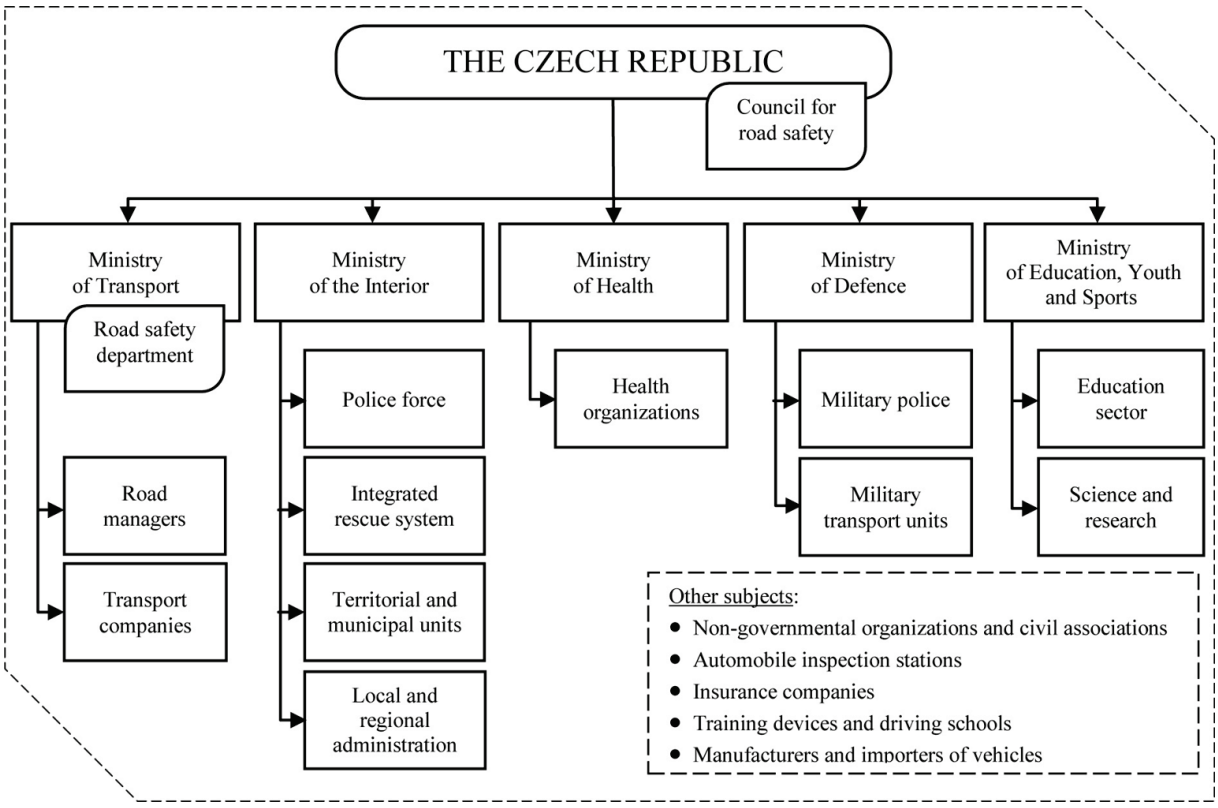

Fig. 1. Road safety system elements.
Source: [3].

- Location (road category, regions, towns, etc.)
- Time (seasons, days of the week, day and night, reduced visibility, etc.)
- Cause (of violation of traffic rules)
- Categories of interested parties (pedestrians, cyclists, children, etc.)
- According to other criteria (e.g. the type of driver's license, vehicle operator, vehicle category, age of a vehicle, etc.).

From the overview it is clear that the area of accident prevention requires an assessment of all three components of safety already mentioned, i.e. a human factor, means of transport and the environment. This assessment must provide not only the image of each component separately, but it is important to reveal their interactions.

4. THE CHARACTERISTIC DATA OF ROAD TRANSPORT IN THE CZECH REPUBLIC

The evaluation in the field of road safety (and generally other transport systems) consists of predicting trends and identifying relationships between processes and variables. Here again, it is possible to select a range of relevant data. Without any claim to completeness, the dependence of the number of accidents can be observed and:

- Consequences for the life and health of participants accidents,
- The amount of tangible and intangible damages,
- The number of motor vehicles,
- Development of road infrastructure,
- Interventions performed.

The overview of specific data for selected indicators over the last period is shown in Table 1.

For monitoring of trends in individual categories certain adjustments to the data were required:

- In the category of accidents: a change (increase) in the mandatory reporting threshold for damage occurred three times (in 2001 to CZK 20,000 in 2006 to 50,000 CZK, and in 2009 to CZK 100,000) during the reporting period [7],
- in the category of deaths due to road accidents and deaths which take place within 30 days after the accident,
- The transport performance expressed a simple sum of the values for passengers and freight,
- Categories of road vehicles is the sum of the number of registered motorcycles, passenger cars, buses, lorries, road tractors and special purpose road vehicles; not include semi-trailers and trailers.

Table 1. Selected statistical data on road transport of the Czech Republic for the period 1999-2016.

Year	Accidents	Consequences		Transportation output [bn. Tkm+Pkm]	Length of roads [Km]			Road vehicles [Mio. pcs]
		death	serious injuries		roads and motorways	local roads	total	
1999	225,690	1,455	6,093	107,96	55,432	72,300	127,732	4,548
2000	211,516	1,486	5,525	112,33	55,408	72,300	127,738	4,504
2001	185,664	1,333	5,493	111,34	55,427	72,300	127,727	4,358
2002	190,718	1,431	5,492	120,02	55,422	72,300	127,722	4,678
2003	195,851	1,447	5,253	123,37	55,447	72,957	128,404	4,847
2004	196,484	1,382	4,879	122,10	55,500	72,927	128,427	4,991
2005	199,262	1,286	4,396	120,70	55,510	72,927	128,437	5,249
2006	187,965	1,063	3,990	129,50	55,585	72,927	128,512	5,491
2007	182,736	1,222	3,960	129,20	55,584	72,927	128511	5,762
2008	160,376	1,076	3,809	132,48	55,654	74,919	130,573	5,988
2009	74,815	901	3,536	126,73	55,719	74,919	130,638	5,999
2010	75,522	802	2,823	125,74	55,752	74,919	130,671	6,075
2011	75,137	773	3,092	129,59	55,742	74,919	130,661	6,178
2012	81,404	742	2,986	124,51	55,717	74,919	130,636	6,341
2013	84,398	654	2,782	128,57	55,761	74,919	130,680	6,360
2014	85,859	688	2,762	130,36	55,748	74,919	130,667	6,499
2015	93,067	660	2,540	138,41	55,738	74,919	130,657	6,866
2016	98,864	545	2,580	-	-	,-	-	-

Source: [4] [5] [6]

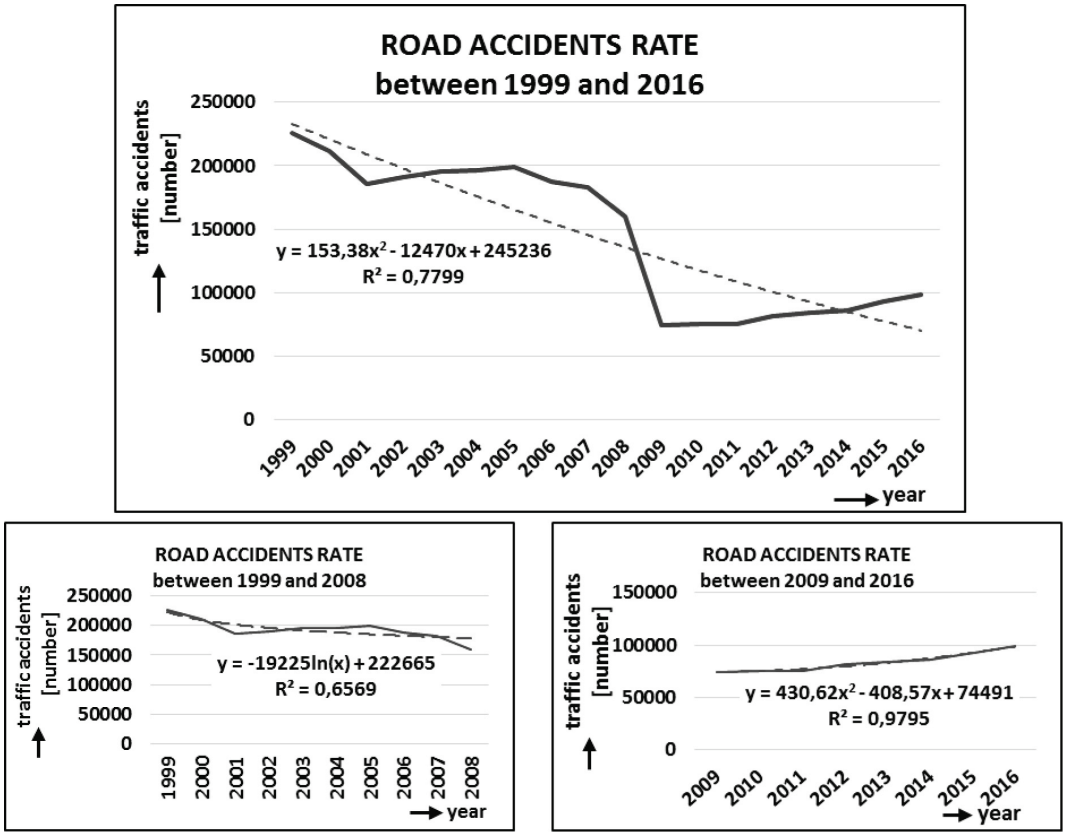

Fig. 2. Development of accidents of road transport in the Czech Republic.
Source: own processing.

The key parameter monitored in terms of road safety is the development trend of accidents which is shown in Figure 2 below.

The chart shows that the rules of reporting accidents in 2009 (Law no. 361 // 2000 Coll. on Road Traffic and on Changes to Certain Laws) brought off a significant reduction in recorded accidents. There was an immediate annual decline in traffic accidents in 2009 to about 47% of the previous year 2008. From this year the number of accidents increased with an annual average of 4.6%. For all investigated regression function, the curve has the highest reliability, precisely the trend of development in the period 2009 to 2016.

The second relevant parameter of road safety are the consequences for the lives and health of victims of traffic accidents. Development trends are shown in Figure 3 below.

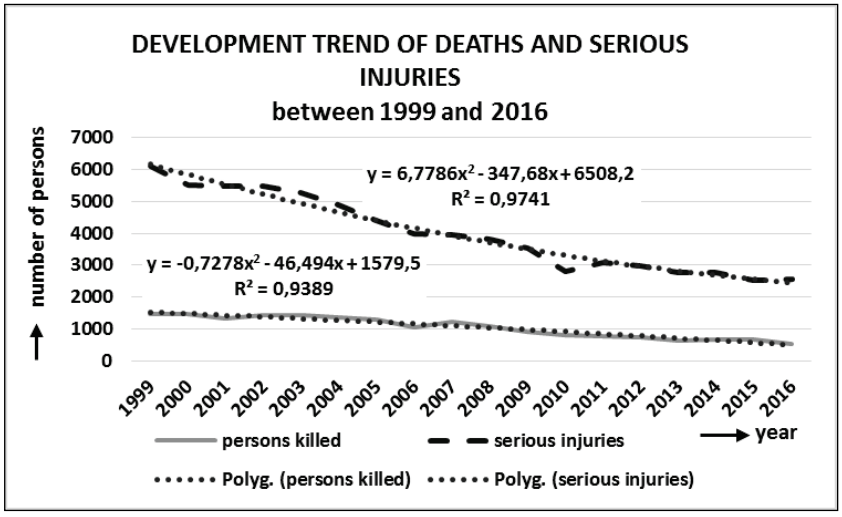

Fig. 3. Development trend of deaths and serious injuries of road transport in the Czech Republic.
Source: own processing.

Development trends of deaths and serious injuries are not substantially affected by changes in the reporting of accidents. The regressions function in both high reliability and confirm steady decline over the trial period. Progressive decline occurred in the decline in fatalities (by 3.7 %) compared with severe injuries (by 3.4 %).

For a deeper analysis of the road safety it is necessary to examine the context of traffic accidents and their consequences with other possible indicators. Trends in selected areas are shown in Figure 4 below.

Selected areas clearly characterize the environment and the intensity in which the road transport takes place. Although the overall trend in the period under review in all three cases is upward, each of these three areas have different growth rates. According to statistics, during the period under review one could observe the highest relative growth in the number of road motor vehicles, namely the annual average of 3.13 % - roughly a half of the annual rate of 1.76 % with increased road performance. The smallest annual growth of 0.14 % was recorded for road infrastructure, especially as far as the length of roads is concerned. Regressions function shows a relatively high reliability in all three cases, and the highest in the case of motor vehicles.

To determine the significance of the selected data sets of road transport it is necessary to assess the relationship between them. The various correlations, along with the anticipated trends in each category will allow to more accurately predict the performance of real time-bound targets in road safety.

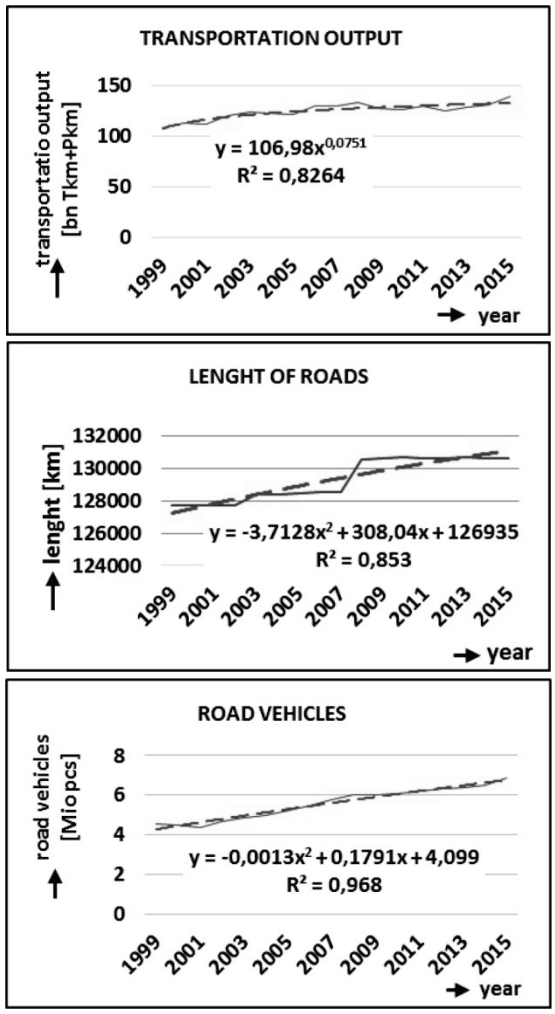

Fig. 4. Development trends of some other parameters of road transport in the Czech Republic.
Source: own processing.

Scatter plot expressing the relationship between the number of accidents and their consequences on the health and life of traffic accidents is shown in Figure 5.

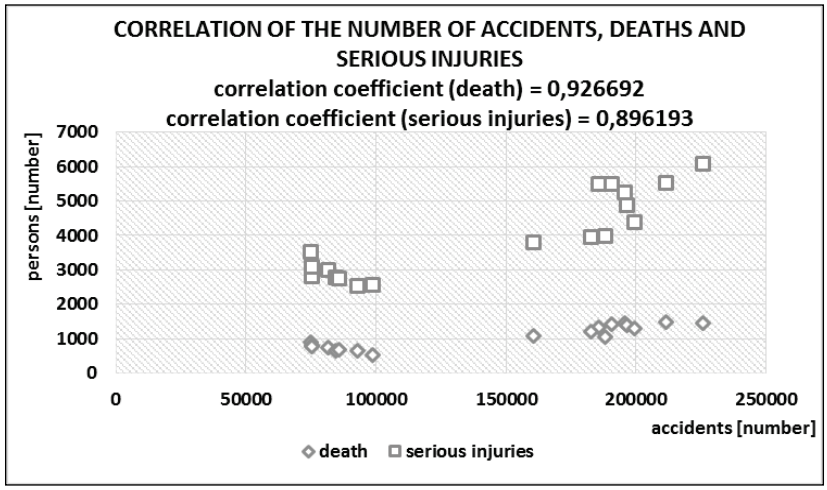

Fig. 5. Scatter plot of accidents, fatalities and serious injuries of road transport in the Czech Republic.
Source: own processing.

Based on the values of the correlation coefficient, we can take it for granted that the number of deaths and severe injuries is closely linked to the development (increase or decrease) of the number of accidents.

Summary results of correlation variables of the file are shown in Table 2.

Table 2.Correlation coefficients of selected data from the road transport sector of Czech Republic.

Considered category		Correlation coefficient
Number of accidents	Number of casualties (deaths)	0.926692
	Number of seriously injured	0.896193
	Transport performance	-0.622537
	Length of roads	-0.931329
	Number of motor vehicles	-0.861661
Number of casualties (deaths)	Number of seriously injured	0.962850
	Transport performance	-0.728904
	Length of roads	-0.928818
	Number of motor vehicles	-0.943877
Number of seriously injured	Transport performance	-0.834001
	Length of roads	-0.923878
	Number of motor vehicles	-0.975489
Transport performance	Length of roads	0.743843
	Number of motor vehicles	0.866267
Length of roads	Number of motor vehicles	0.929865

Source: own processing.

5. SAFETY OF RAIL TRANSPORT SYSTEM

Rail transport, along with road transport, forms in the Czech Republic the backbone of the transport system of the state. In terms of road safety, some peculiarities should be noted, which make both transport systems different.

Rail transport has in comparison with road especially these specifics:

- The number of entities involved in the transport and shipping process of rail transport is significantly smaller (a small number of carriers, essentially a single administrator infrastructure etc.)
- Limited access to infrastructure, almost excluding the general public,
- Internal system maintenance and repair of transport infrastructure, including basic powers and resources to deal with emergencies,
- Considerable share of technical security equipment increases the level of security in railway transport (helping or taking over operations staff)
- Limited opportunities for immediate intervention by an operator of mobile devices in danger (to avoid collisions, the longer the time to stop for acute, etc.)
- Generally more negative consequences of accidents, especially materially,
- For statistics purposes and prevention it is not necessary to monitor such a large amount of data as in road transport (e.g. daily, nightly, weekly time of accident, age, vehicle type approval for the management, etc.)
- On the other hand, however, there is a need to monitor much more in detail and it is mandatory to report common safety indicators for statistics required by the European Railway Agency [8].

The criteria on statistical data have been also recently adjusted in rail transport security referring to rail. Significant changes were mainly internal categorization of incidents and adjustments for uniform reporting within the EU, and partly changes in structures and competencies of entities operating in the railway sector. For the assessment of issues related to railway accidents the data set with relatively shorter period of time has been selected, and it is indicated in Table 3.

Table 3.Selected statistical data rail transport in the Czech Republic for the period 2006-2015.

Year	Accidents	Consequences [pers]		Transportation output [bn. Tkm+Pkm]	Construction lengthof lines [km]	Length of railway lines [km]
		death	serious injuries			
2006	233	52	89	22,701	15,844	9,597
2007	115	25	101	23,202	15,810	9,588
2008	133	44	139	22,210	15,716	9,586
2009	113	26	92	19,263	15,677	9,578
2010	125	48	107	20,329	15,666	9,568
2011	99	29	74	20,985	15,656	9,572
2012	97	26	66	21,463	15,636	9,570
2013	91	24	52	21,477	15,607	9,560
2014	104	29	60	22,218	15,578	9,559
2015	94	29	53	23,386	15,570	9,566

Source: [9].

The basic indicator of development of railway safety in the Czech Republic during the period under review is the trend of serious accidents, which is shown in Figure 6. The graph shows that the most appropriate regression function for expressing the course of this dependence is a power law function.

From other potential areas transport performance and longitudinal data on the network have been selected. Representation of trends is shown in Figure 8.

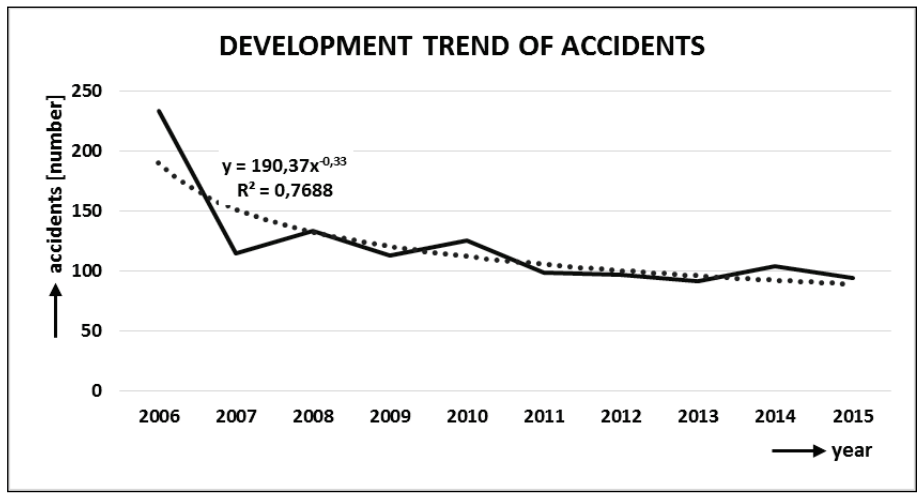

Fig. 6. Development of accidents of railway transport in the Czech Republic.
Source: own processing.

The course of the second major indicator of safety in railway transport is frequency of fatal and serious injuries, and serious accidents in different years, as shown in Figure 7.

For both monitored parameters the values for individual years are quite sparse. It represents a relatively lower level of reliability indicators, particularly in the event of death. Trends in the development of best approximate logarithmic regression function (a marker of death) and exponential regression function (a marker of severe injuries).

Reported transport performances are also the sum of the values for passengers and freight, and in the period under review they vary in the range ± 10%. Trends of the length of the tracks and tracks are of a downlink character, with a greater annual decrease in the length of the tracks with structural length (0.19%).

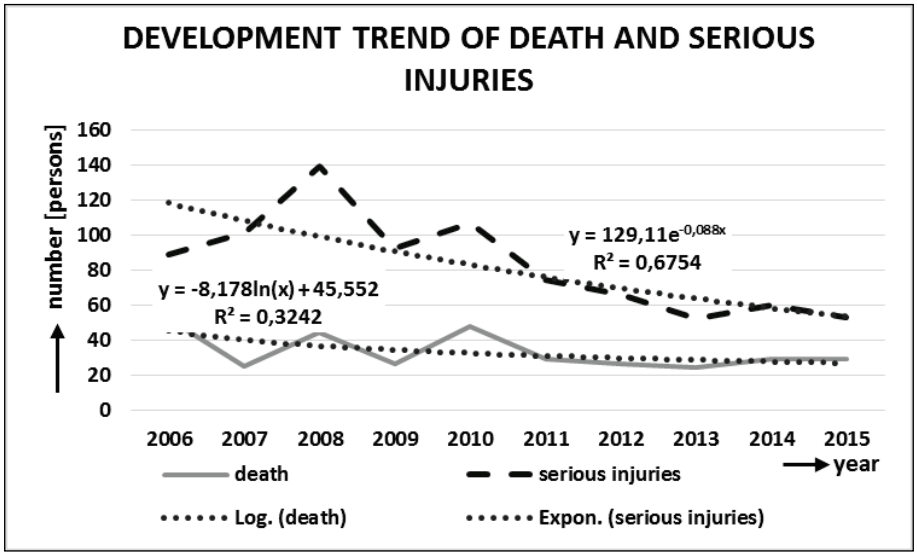

Fig. 7. Development trend of deaths and serious injuries of railway transport in the Czech Republic.
Source: own processing.

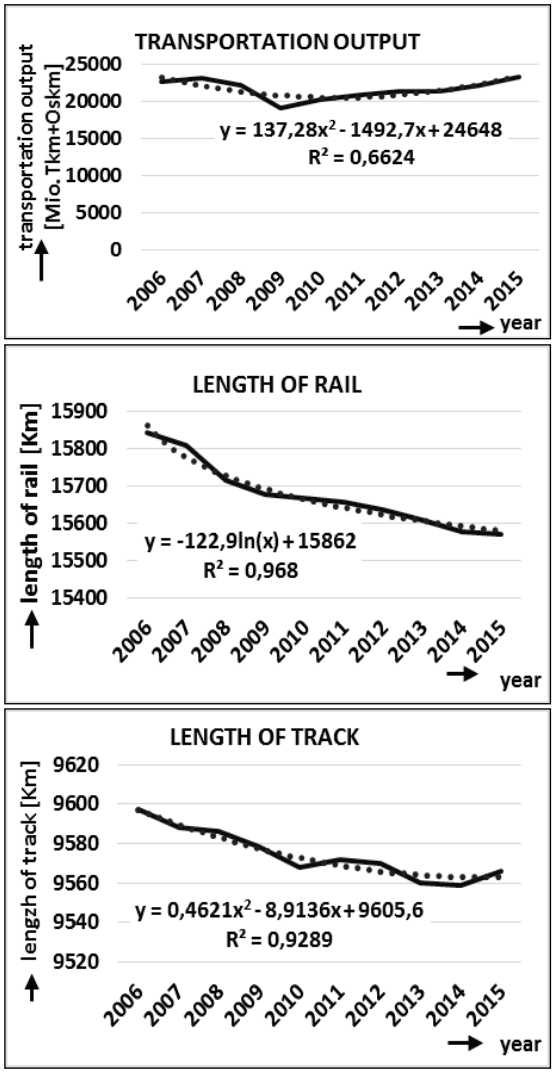

Fig. 8. Development trends of some other parameters of rail transport in the Czech Republic.
Source: own processing.

Scatter plot expressing the relationship of serious accidents and their consequences on the health and lives of participants is given in Figure 9.

Based on the determined correlation coefficients a certain degree of dependence variables of serious accidents and consequences, with a greater degree of dependence file has fatal consequences was demonstrated.

The survey correlation relationships between other selected variables showed:

- Correlation coefficient between the number of serious accidents and traffic performance has a value of 0.199305;
- Correlation coefficient between the number of serious accidents and length of railway has a value 0.766198;
- Correlation coefficient between the number of serious accidents and length of lines has a value 0.762199;
- Correlation coefficient between the number of deaths and severe injuries has a value of 0.582041.

When comparing the correlation relationship while assessing road transport and rail transport, there is a clear evidence of dependency between the number of accidents and the length of the transport route, and considerably lower the coefficient of correlation between the number of deaths and serious injuries.

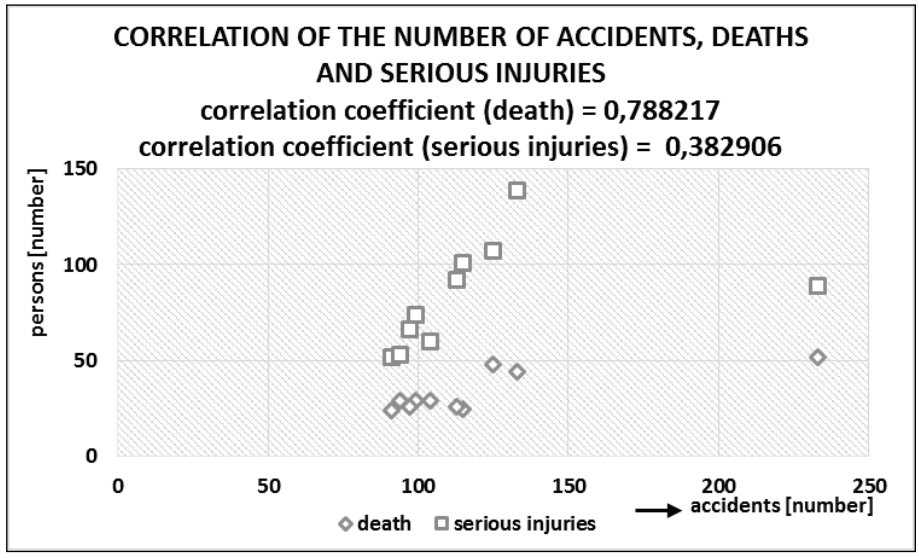

Fig. 9. Scatter plot of accidents, fatalities and serious injuries of rail transport in the Czech Republic. Source: own processing.

6. CONCLUSIONS

The article suggests possible approaches to solving problems related to the security of transport systems. It should be seen that the solution have been used basing only on readily available statistical files that do not always demand for complete and sufficient data. Therefore, many of the trends identified which reflect developments are valid for a limited period of time only. A certain distortion is also due to the selected areas where only quantitative aspects were examined, and it still means simplifying assumptions. While qualitative factors considered most of the categories, they can also change significantly enough to draw conclusions and look at the importance (weight) of data when assessing the safety of a particular mode of transport.

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