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ANALYSIS OF EXTERNAL FACTORS AFFECTING TRANSPORT PROCESS SAFETY

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Abstract

Transportation systems belong to the category of systems whose operation safety depends on many factors including: technical state of transport means, behavior of people involved in the system operation and maintenance and its environment, and finally the environmental factors. The system environment is referred to as all the elements, which, though not belonging to the system, are closely related to it. The environment, which is of interest for the authors of this paper, is the road infrastructure and atmospheric conditions. Construction solutions of the infrastructure, the road surface type and condition, temperature, visibility, precipitations, and time of day are referred to as external factors whose impact involves changes in safety of the transportation system operation. The impact of external factors can be in different forms and can affect the transport means as well as people involved in the system operation, especially the drivers. The literature provides a concept of excessive sense of a driver's safety, which can be caused by good road conditions, dry and good road surface, etc. This is of particular importance in case of public transportation systems providing transport services on the territory of a town where the effects of external factors account for nearly 44% of adverse events causes. This study deals with identification of these factors and assessment of their influence on the analysed transportation system safety.

Keywords: *safety, forcing factor, transport process*

1. Introduction

Safety of provided transport services largely depends on the impact of forcing factors, which include operational, external and anthropotechnical ones. In literature [1], a factor is referred to as a phenomenon causing changes in the state of a system, being an effect of a physical or/and psychological process. In this study, a factor has been defined as one of the components conditioning (degrading) changes of the state, independent on the researcher, and being the subject of his/her interest. Fig. 1 shows a percentage share of forcing factors harmful impact, including external factors which account for nearly 44% of adverse events in transportation systems operating in built-up areas. [2]. *Changes of forcing factors states cause a change in a system operation safety which leads to a change in the safety of transport services provided by the system.* Thus, a system operation safety assessment does not apply to the system state but rather to the transport process carried out by this system.

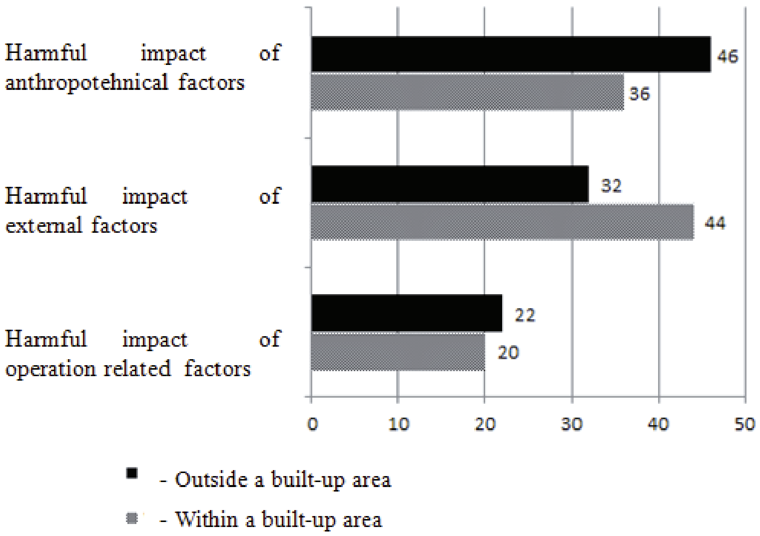

Fig. 1. Percentage of forcing factors impact on the occurrence of adverse events [2]

2. Assessment model of an adverse event occurrence from the point of view of a harmful impact of people involved in the system operation and its environment

The impact of external factors can be in different forms and can affect the transport means as well as people involved in the system operation, especially the drivers. The literature provides a concept of excessive sense of a driver's safety, which can be caused by good road conditions, dry and good road surface, etc. In Fig. 2, there is an overall structure of a tree for adverse event occurrence caused by people involved in the system operation, due to poor condition of the surrounding environment.

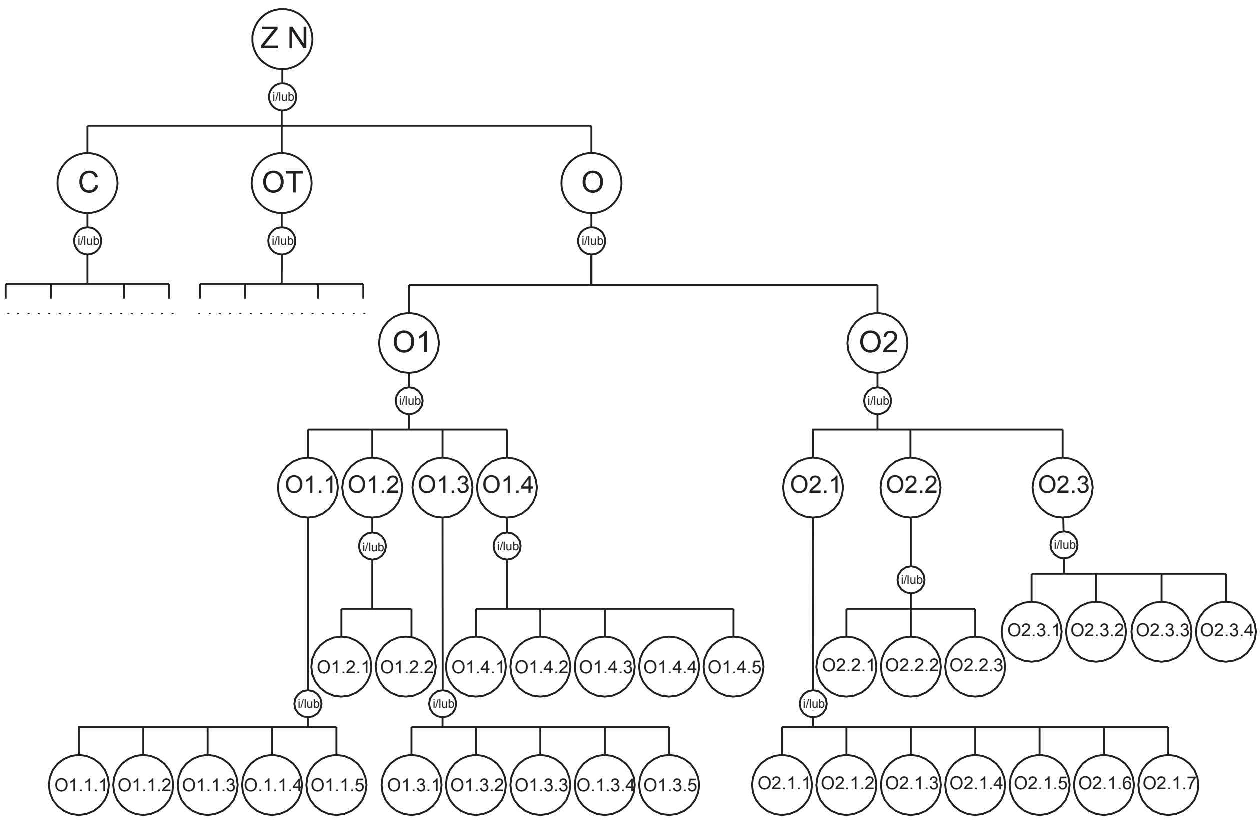

Fig. 2. The overall structure of the tree of adverse events occurring in transport systems

3. Identification of factors causing occurrence of an adverse event

Excessive feeling of safety is a notion connected with drivers' psychology and refers to their wrong decision making due to excessive self-confidence, which can be caused by:
- believing in one's good driving skills,
- the vehicle construction qualities (equipment with active and passive safety systems and its big power etc.),
- good environmental conditions (both atmospheric and road infrastructure).

The authors of this article have made an attempted to identify external factors which lead to occurrence of a road event in a given time interval. The research was performed in the system of public transportation, which provides transport services on the territory of a town and its suburbs. The collected data covers time from 1.01.2006 to 31.12.2010. Values of adverse events occurrence probabilities have been determined for established external factors, presented in Tab. 1 and Tab. 2.

Tab. 1. Values of adverse event occurrence probabilities under specific atmospheric conditions and the specific time of the day

Environmental factors		Code	$P(A)$
Weather	Sunny	O1.1.1	0.569
	Cloudy	O1.1.2	0.211
	Foggy	O1.1.3	0.018
	Rainy	O1.1.4	0.146
	Snowfall	O1.1.5	0.056
Environmental factors		**Code**	$P(B)$
Visibility	Good	O1.2.1	0.729
	Limited	O1.2.2	0.272

Environmental factors		Code	$P(C)$
Temperature	⟨–20°C, – 10°C)	O1.3.1	0.006
	⟨–10°C, 0°C)	O1.3.2	0.101
	⟨0°C, 10°C)	O1.3.3	0.367
	⟨10°C, 20°C)	O1.3.4	0.326
	Over 20°C	O1.3.5	0.200
Environmental factors		**Code**	$P(D)$
Hour	⟨05:00, 08:00)	O1.4.1	0.096
	⟨08:00, 13:00)	O1.4.2	0.263
	⟨13:00, 17:00)	O1.4.3	0.317
	⟨17:00, 22:00)	O1.4.4	0.229
	⟨22:00, 05:00)	O1.4.5	0.095

Tab. 2. Values of adverse event occurrence probabilities in a particular state of infrastructure

Infrastructure factors		Code	$P(E)$
Road surface condition	Dry	O2.2.1	0.729
	Wet	O2.2.2	0.211
	Slippery	O2.2.3	0.060
Infrastructure factors		**Code**	$P(F)$
Road surface condition	Asphalt	O2.3.1	0.895
	Concrete	O2.3.2	0.042
	Boulder pavement	O2.3.3	0.023
	Cobblestones	O2.3.4	0.040

According to the above table and figure, this is sunny weather in which adverse road events happen most frequently (probability of adverse event occurrence throughout a year is $P(\text{O1.1.1}) = 0.569$). The same applies to good air visibility $P(\text{O1.2.1}) = 0.729$). Whereas, for temperatures ⟨0°C, 20°C) the probability of adverse event occurrence is $P(\text{O1.3.3}) + P(\text{O1.3.4}) = 0.693$.

Drivers, having a sense of comfort and safety, make risky decisions (exceed speed limits, fail to give way, etc.), which eventually lead to occurrence of adverse events. According to this research, apparently good weather conditions can be a direct cause of adverse road events occurrence.

Another important issue is the time of day in which an event happens. For the needs of this

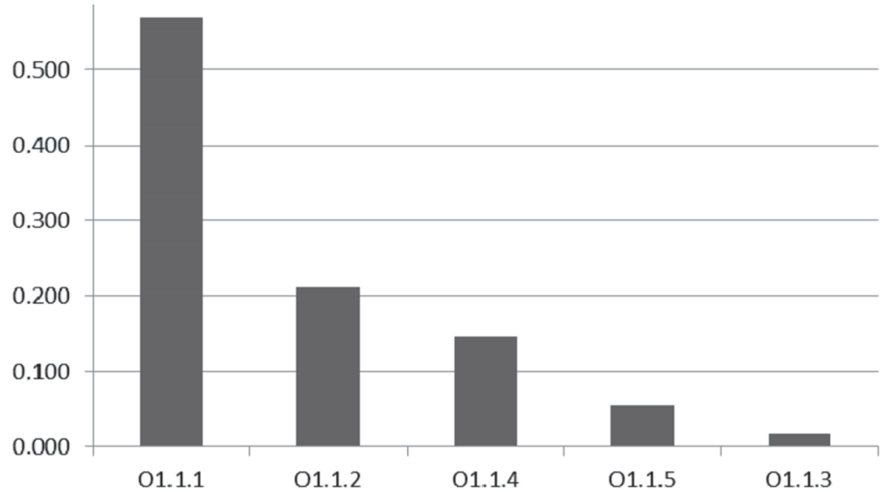

Fig. 3. Values of the probabilities of adverse event occurrence in specific weather

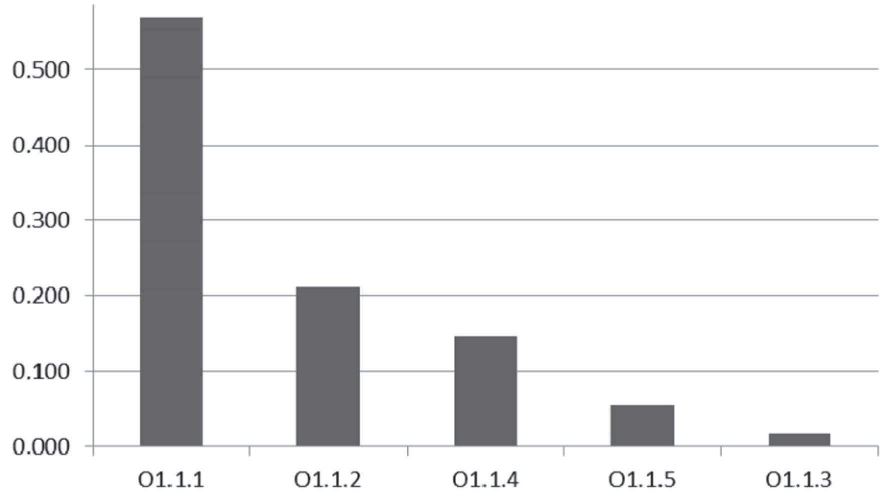

Fig. 4. Values of adverse event occurrence probabilities in a specific air temperature

paper, a division of day and night into five rush hours has been made in consistence with the division accepted by the analysed transportation system. The probability of an adverse event occurrence in particular traffic rush hours is presented in Tab. 1 and in Fig. 5. According to the data shown in Tab. 1 and Fig. 6, the highest probability of adverse event occurrence has been found for the afternoon rush hour P(O1.4.3) = 0.317 and for the morning one P(O1.4.2) = 0.263 which is caused by the highest traffic intensity in the analysed urban agglomeration.

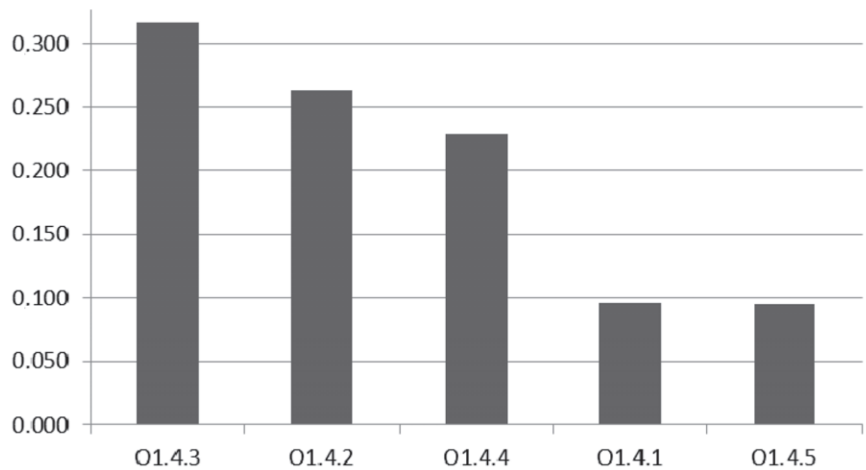

Fig. 5. Values of the probabilities of the occurrence of an adverse event specific time of the day

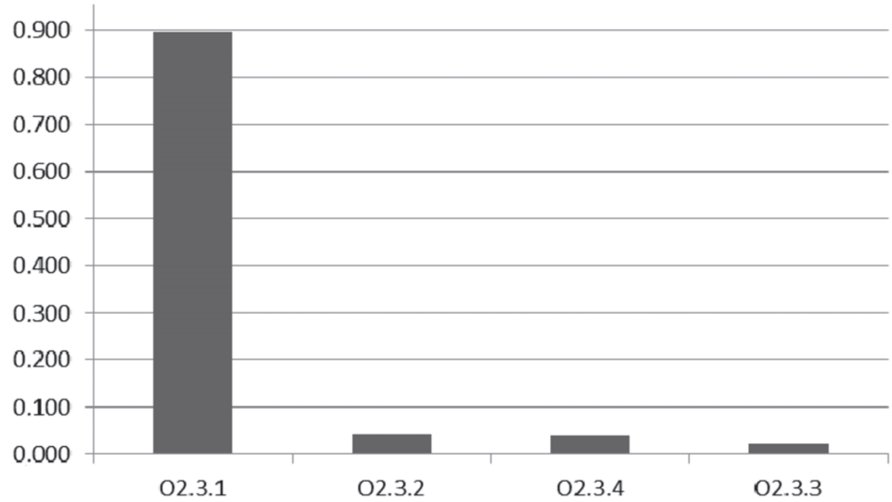

Fig. 6. Values of the probabilities of an event on a specific adverse road surface

The next stage of this research was to analyze the state and type of road surface on which adverse events took place. Since the research object is a system of public city bus transport which provides 90% of its services on the territory of a town, majority of its roads are made of asphalt – Fig. 6 and most road events were reported to have happened on dry surface – Tab. 2.

4. Assessment model of external factors impact on the analysed transport process safety

Among the analysed factors, there are six variables:
A – weather,
B – visibility,
C – temperature,
D – hour,
E – road surface condition,
F – type of road surface.

Let us consider the product of events. $A \cap B \cap C \cap D \cap E \cap F$, the highest probability is equal to $0.569 \cdot 0.729 \cdot 0.367 \cdot 0.317 \cdot 0.749 \cdot 0.825 = 0.03249679$. Probability of the product of events, with the assumption that these events are independent, is equal to:

$$P(A \cap B \cap C \cap D \cap E \cap F) = P(A) \cap P(B) \cap P(C) \cap P(D) \cap P(E) \cap P(F)\,. \tag{1}$$

Events *A*, *B*, *C*, *D*, *E*, *F* generate probability space with $5 \cdot 2 \cdot 5 \cdot 5 \cdot 3 \cdot 4 = 3000$ elements. Each element of the space is assigned with a probability according to formula (1) (the sum of probabilities is equal to 1). The new random variable *X* is introduced – random variable *X* assumes $n = 3000$ probability values.

Random variable *X* assumes the values from interval $\langle 2.55802 \cdot 10^{-9}, 0.03249679 \rangle$. The mean value $\overline{X} = 0.000333$, standard deflection $S_X = 0.00161227$, coefficient of variability. $v = 4.8368$. The value of variability coefficient at the level 483.68% confirms very high variability of the random variable.

It is necessary to find out what is the distribution of random variable *X*. For this purpose, random variable. $Y = -\ln(X)$ has also been considered. On the basis of an analysis it turned out that, the distribution of random variable Y was normal with parameters: $\overline{Y} = 11.21498$ and $S_Y = 2.774097$.

Consistence of random variable *Y* distribution has been checked by means of two consistency tests: λ – Kolmogorov, and χ^2 – Poisson tests.

For Kolmogorov test λ, values of test statistics have been calculated $\lambda = 0.304$, which given value $P = 0.98$.

For Poisson test χ^2, $\chi^2 = 22.52$ has been calculated which gives value, $P = 0.834$.

The obtained results of distribution parameters confirm consistence of the empirical distribution with the normal one, which is presented in Fig. 7 and Fig. 8. Fig. 7 shows a diagram of empirical and theoretical distribution functions, in Fig. 8 empirical and theoretical density diagrams are shown.

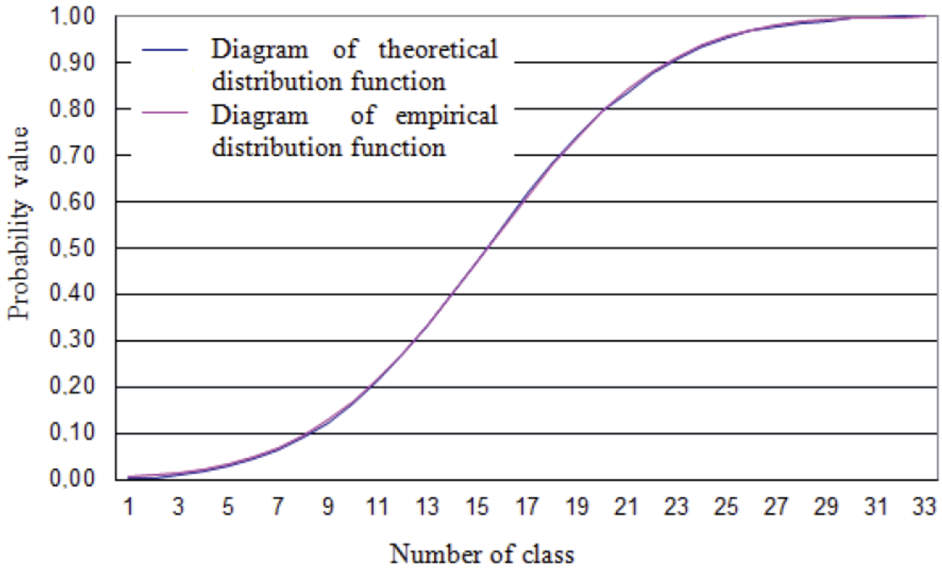

Fig. 7.Comparison of empirical and theoretical distribution function

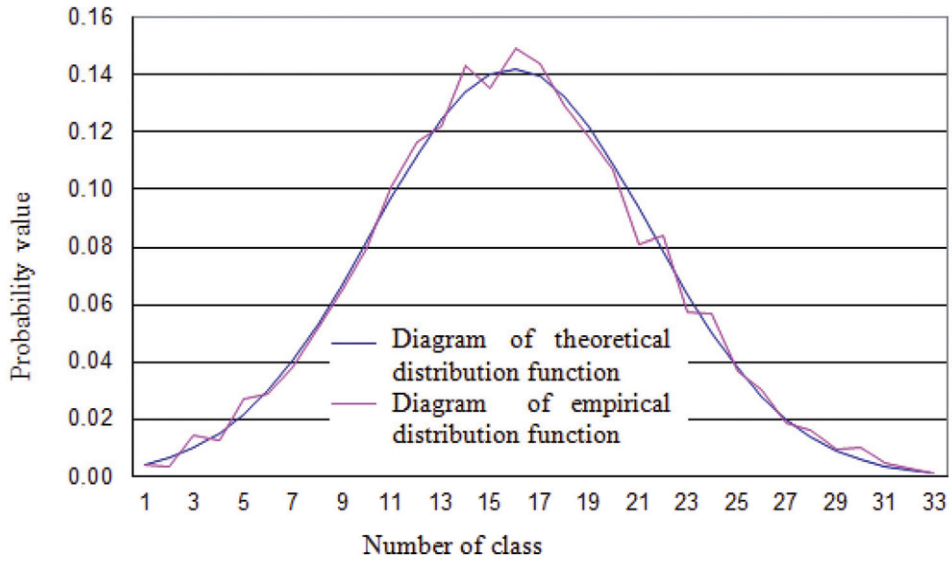

Fig. 8. Comparison of empirical density with theoretical

How to determine the value of probability $P\{X > p\}$:

$$P\{X > p\} = P\{\ln X > \ln p\} = P\{-\ln X < -\ln p\}, \tag{2}$$

$$P\left\{\frac{-\ln X - my}{Sy} < \frac{-\ln p - my}{Sy}\right\} \cong \phi\left(\frac{-\ln p - my}{Sy}\right), \tag{3}$$

where ϕ is a distribution function of normal standardized distribution, expressed by the following formula:

$$\phi(x) = \frac{1}{2\pi} \int_{-\infty}^{X} e^{\left(\frac{-t^2}{2}\right)} \mathrm{d}t. \tag{4}$$

8. Conclusion

The authors of this paper have undertaken an attempt to identify the impact of environmental factors on occurrence of adverse road events. According to the carried out analyses, most accidents occur under the conditions of sunny weather, good visibility, moderate temperatures, during the day, on a dry asphalt road. It is partly due to the fact that such weather conditions are the most common in the year, however, the above-discussed sense of comfort and safety is not irrelevant, either. While driving a vehicle in hard conditions, drivers to not undertake a risk connected with difficult maneuvers, which could lead to occurrence of a road event.

However, it is advisable to identify places where adverse road events happen most often in the examined urban agglomeration and analyse to what extent infrastructure affects the transport process safety.

Research is to be continued in order to show in which parts of the town and on which infrastructure elements the events are most frequently reported. This will provide the basis to make proper assumptions for transportation safety improvement.

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