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Identification and Assessment of Transport Systems Operation Quality

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Abstract

The basis of a transport system operation is accomplishment of set goals in specified conditions, place quantity and time. From an analysis of the literature it results that the reasearch on these systems operation quality is crucial for the processes of service - repair, control, fuel supply and diagnosis, especially for machines and dvices used in them. The discussed systems are classified as socio-technical ones of the type <H-M-E> (human–machine–environment), including the transport system which is the research object of this paper. On the basis of the authors' own experimental tests results and identification of processes which take palce in the research object, a method for assessment of such transport systems operation quality has been presented in the article. The authors of the paper have made an attempt to develop a model for assessment of undesirable impact of actions of people present in the system and its environment.

Keywords: transport system, quality

1. Introduction

The study concerns operation quality of complex operating systems, especially transport ones. In these systems transports of passengers and goods are carried out by land, water or air. The main goal of operation of such systems is accomplishment of a transport tasks in a specified environment, quantity time and with the use of technical objects and under the influence of environmental factors. In connection

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with this, an assessment and provision of the required operation quality in terms of safety, efficiency, reliability, availability and environment friendliness, taking into consideration the economic aspect, is essential for the systems operating. The studied transport systems belong to the group of socio-technical systems of the type <H-M-E> (human-machine-environment), whose operation quality assessment is performed on the basis of features describing actions of operators, technical objects operated by them and the environmental factor.

2. The Research Object

On the basis of identification and analysis of real transport systems it was decided that at particular levels of their decomposition, there can be distinguished the following subsystems:

– logistic, which includes actions connected with the system management, information flow and processing, and maintenance of used by the system means of transport serviceability. This subsystem consists of:
  – decision making subsystem,
  – traffic maintenance subsystem,
  – information subsystem,
  – executive, which deals with accomplishment of the system basic goal, that is, provison of transport services,
  – environment as the main subsystem involved.

A general scheme of a system operating transport means has been demonstarted in Fig. 1.

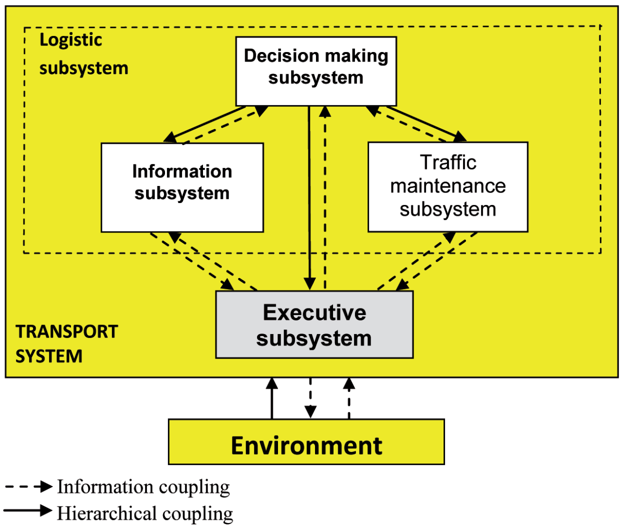

Fig. 1. Scheme of a decomposed system of transport means operation

The decision making subsystem deals with control and supervision of the transport system operation. Within the system of traffic maintenance there are performed actions connected with providing fuel, diagnostics, failure prevention, (servicing on the day of operation, andperiodical survey) and overhauls of the vehicles. The information subsystem covers collecting, processing and transmitting information between particular subsystems, mainly the data on transport tasks accomplishment. Within the executive subsystem, the main goal of the transport system oparation is being accomplished, that is, safe and economical transport over a specified area, in a given quantity and tme with the use of technical objects operated in the system.

The environment performs the function of a cooperating system in which the system goals are being pursued and which has a direct influence on its functioning [3].

3. Method for Assessment of Transport Systems Operation Quality

In this section, there is presented a description of rules on the basis of which the method for assessment of the transport system operation quality has been formulated.

Basing on the literature analysis and the authors' own research, it was found that: the system operation quality is a set of its features, expressed by their numerical values, in given time t, specifying the fullfilment degree of set requirements [3]. It was assumed that the person who makes an assessment establishes a set of criteria for evaluation of K system operation quality. Idendification of a criteria set and determination of their significance is essential for the assessment correctness. The next stage of evaluation includes identification of the research object, and on this basis, having in mind the specified criteria, a set of X features describing the system in terms of its operation quality, is determined.

It must be noted that the set of features accepted for the description of the studied system operation quality consists of two subsets: meqasurable features and immeasurable ones. Immeasurable features include these ones which can not be measured due to being technically complex or because of the researcher's ignorance. Each measurable feature describing studied system X (i=1,2,. . . ,n) needs to have specified allowed variability limits X.. X. . . , corresponding to the system desirable operation quality.

Similarly, for each feature considered to be immeasurable, there should be determined the desirable operation quality conditions in such a way that it will be possible to find whether this feature meets them or not. For this purpose, immeasurable features are provided with different values from 0 to m. Tthis means that in given time t, the system operation is of the derisable quality only when the values of its measurable features are contained within established limits and the immeasurable features fulfill the conditions specified for its correct (desirable) quality.

The assessment process involves checking whether and to what extent K criteria are met by particular features from X set. The assessment is made on the basis of values of the features measured in time t (measurable features) or states in which they occur in given time t (immeasurable features), through assigning appropriate indexes to them. Therefore, the level of the system opearation quality in given time t determines the set of values of significant features {X}i=1,2,. . . .,p accepted for its description from the set point of view.

In this way, the system operation quality determined in tme t,t<tt>, can be described by means of the so called Multidimensional Vector of Quality. The set of features accepted for the system operation quality description (X, X, X. . . ..) determines dimesional space of the assessment. Vector MVQ reflects the system operation quality in time t, whereas, vector Criteria Vector of Quality CVQ is determined on the basis of maximal or desirable values of the considered features. Distances between the ends of vectors CVQ and MVQ, within accepted p – dimensional space, determines the system operation quality assessment Δk. It can be recorded, as follows:

$$\mathbf{\Delta}\overline{\Delta K} = \overline{KWJ} - \overline{WWJ} \tag{1}$$

Since values of the distinguished features, under the influence of forcing factors, undergo changes in time, point M (being the end of vector MVQ, in time interval with length t, in the considered p-dimensional space of states, draws a trajectory which is a representation of the system operation quality changes. It means that the system quality is variable in time as in each axis there occur changes of MVQ [8] vector component values, in the considered p-dimensional space in time (t+ Δt).
A graphic interpretation of the above study has been demonstrated in Fig. 2. A detailed description of the general and resultant mathematical model of transport systems operation quality assessment is presented in works [1,8,9,10].

It has been accepted that on the basis of the distinguished criteria there was determined a set of significant, measurable, variable and independent features whose values, determined in given time t, are the basis for the system operation quality assessment.

It was assumed that X(t), i=1,2,. . . ,p denotes a feature which is time dependent, random variable whose exexution in time t describes the system operation quality. There is considered the vector of quality features of fhe form:

$$X(t) =< X_1(t), X_2(t), ..., X_p(t) >$$

Set of qualities Z=X i=1,2, . . . p, is divided into n-separable subsets Z,Z,. . . Z meeting the below dependencies:

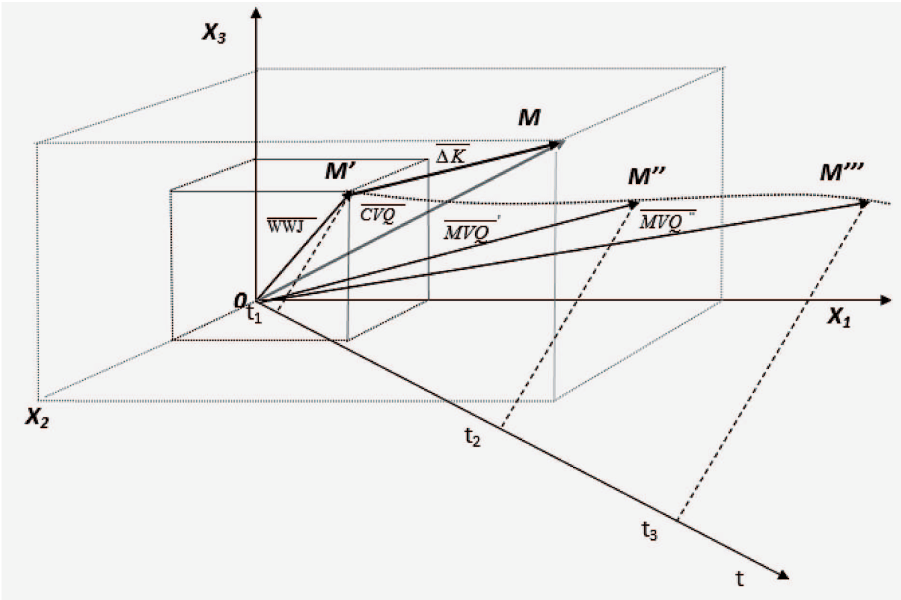

Fig. 2. Graphic interpretataion of transport system operation quality assessment

$$Z_i \cap Z_j = \emptyset \text{ for } i \neq j;$$

$$Z(t) = Z_1(t) \cup Z_2(t) \cup ... \cup Z_n(t) \tag{2}$$

Having in mind that the study is related to operation quality assessment of transport systems of the type <H-M-E>, whose elements are: human (operator), machine (technical object) and the environment, the resultant model of the transport system operation quality assessment takes the form which is described by the below dependence [3]:

$$\begin{aligned} Z_1(t) &= \{X_1(t), ..., X_{k_1}(t)\} \\ Z_2(t) &= \{X_{k_1+1}(t), ..., X_{k_2}(t)\} \\ Z_3(t) &= \{X_{k_2+1}(t), ..., X_{k_3}(t)\} \end{aligned} \tag{3}$$

where: k =p.

For the studied system there has been defined a random process reflecting its operation quality of the form:

$$Z_x(t) = \sum_{i=1}^{p} \alpha_i X_i(t) \tag{4}$$

where : $\alpha_i \geqslant 0, \sum_{i=1}^{p} \alpha_i = 1,$

where: i=1,2,. . . ,p, denote values of quality weights for particular features, determining operation quality of the studied system.

In order to determine weights for particular features which can be found in the model overt description, it has been proposed to use the method of matrixes of meaning [3].

Zx(t) – is a random process which is a mixture of processes X (t), i=1,2,. . . .,p.

For the process Zx(t), iequality (5) is obvious:

$$Z_x(t) \leqslant \sum_{i=1}^{p} \alpha_i q_i \tag{5}$$

for t∈T.

For the system analyzed in a given moment t, it is possible to define the length between the point describing the system operation quality in time t (in a geometric interpretation) the point is the end of MVQ from the model point (point determining CVQ) by means of formula: (6)

$$d(X(t), q) = \left(\sum_{i=1}^{p} (X_i(t) - q_i)^2 \right)^{\frac{1}{2}} \tag{6}$$

Formula (6) can be used as a tool for classification of systems in terms of their operation quality.

4. Transport Systems Operation Quality Assessment Criteria

In the process of the transport system operation quality evaluation there were performed tests on the basis of which there was established a set of the most significant criteria distinguished for its evaluation, from the accepted point of view. For this purpose expert investivations were carried out and basing on them a set of eleven criteria was established which were presented to the analyzed system users (outsider observers) for evaluation.

The people who were to make the assessment included users of the studied system differentiated in respect of age, sex, education and occupation. The statistical person was one user – a simple unit and the number of the set of respondents was N=150. The variability criterion was – significance of the assessed criteria in points. The assessment scale was [0,1,. . . ,10].

It was assumed that according to the accepted assessment scale the lowest threshold of significance deciding whether the criteria are to be taken into consideration is 5.

On the basis of carried out surveys, there was determined mean values of the grades given to particular criteria which were compared in a chart, in Fig. 3. The distinguished criteria include: safety (K1), the transport service accomplishment time (K2), availability (K3), ergonomics (K4), the user's understanding (K5), informativeness, (K6), demand (K7), reliability (K8), energy efficiency (K9), esthetics (K10).

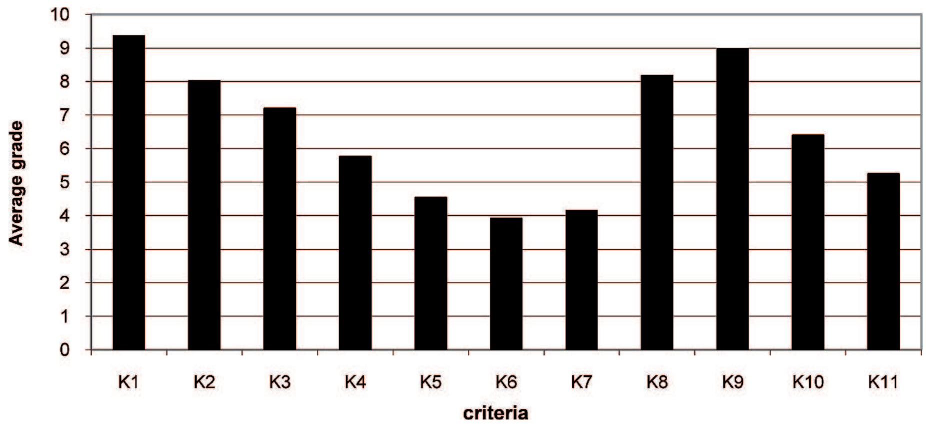

Fig. 3. Mean values of grades given to the considered set of criteria

In order to establish significance of the considered criteria, there were made: a statistical analysis of the obtained results of carried out investigations and a test of significance of the correlation coefficient.

Histogram of distribution of the obtained grades for the most significant criterion – safety (K1), has been presented in Figure 4.

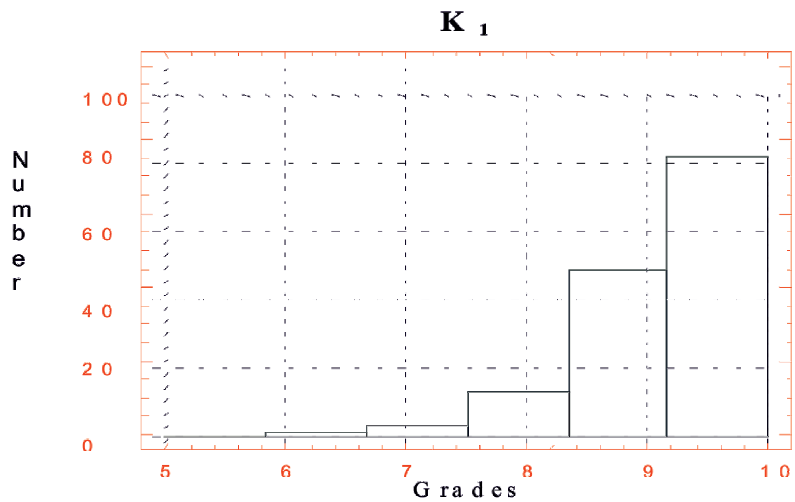

Fig. 4. Histogram of distribution of grades obtained for criterion K1 – safety

On the basis of the correlation coefficient significance test results it can be said that particular criteria are strongly correlated with each other and they make up a redundant set. This means that some of the considered criteria can be neglected with a small loss of provided by the neglected criterion information which is provided by the remaining, strongly correlated ones [4].

A analysis of the tests results provide information on the transport means users' preferences and requirements. An analysis of statistical research, especially the arithmetic mean which is the most effective unloaded estimator of unknown expected value [11], proves that according to users of the studied transport system the most important criteria are safety (9,35) and punctuality (8,96) which were given the maximal number of points by majority of the respondents. Apart from this, values of variability coefficient for these criteria are the lowest for the analyzed set and they are, respectively: 9,99% and 10,2%. This means that the responses given by the respondents on the subject of the above criteria are the least diversified.

The criteria – time of the service accomplishment and reliability were given grades whose mean value exceeded 8 points which makes them significant and they should also be accounted for in the process of the studied system operation quality assessment.

On the basis of carried out investigations and in consistence with the accepted significance threshold being 5 points, a set of eight most important criteria has been distinguished which are accounted for in the resultant model of the studied transport system operation quality assessment [1]: safety, time, availability, ergonomics, reliability, punctuality, cost, esthetics. It should be noted, though, that according to respondents the most significant criteria were safety and punctuality which were given the biggest number of points and which gives them priority in terms of the transport system operation quality.

5. Safety as a Criterion of Transport System Operation Quality Assessment

In result of the carried out research there was distinguished a resultant set of assessment criteria and according to the transport system users safety and punctuality are of highest significance and, therefore, they will be used for further consideration by the authors of this paper.

Safety of the transport system operation means its state for which values of the distinguished features, describing the system in a given time interval t, t [t t], are contained within fixed limits with defined levels of the impact of forcing factors.

These factors can be divided into:

— functional (in the system) – factors affecting the transport means due to performance of functions connected with its services;

— external – factors characterizing impact of the environment (not connected with its functioning);

— anthropotechnical – factors affecting the elementary executive subsystem in result of peoples' actions eg. operators' errors, inappropriate behaviors of apssengers and sidewalkers.

On the basis of the authors' own research, a general algorithm of the research object opearation safety has been built. In connection with the fact that the studied transport system is a socio-technical one of the type <H-M-E>, this algorithm is built with a differentiation of blocks concerning safety: peoples' actions, functioning of the transport means and the environmental impact (Fig. 5). Description of the algorithm blocks have been presented in Table 1.

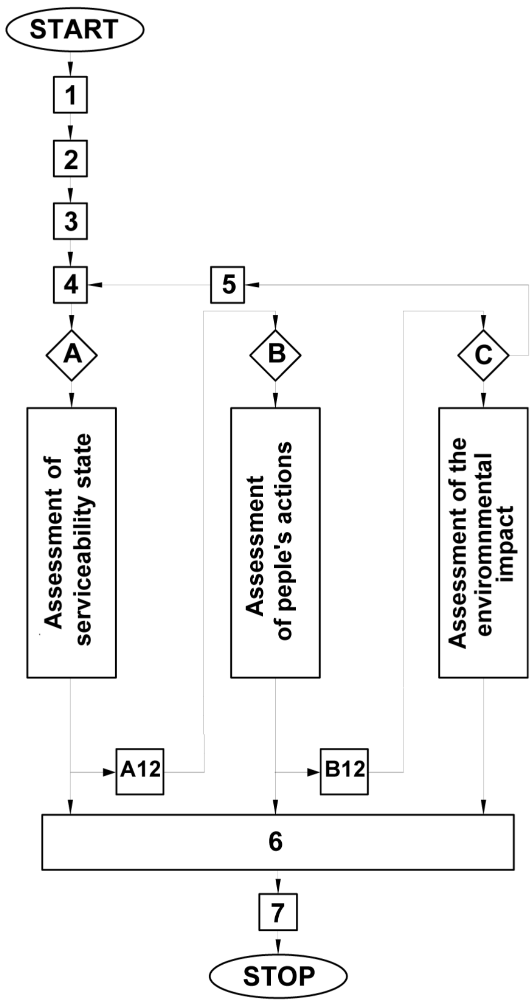

Fig. 5. Algorithm of the impact of factors affecting safety of the transport system operation

As an example of the carried out research on the transport system opretion quality, especially its safety, there was made an anlysis of events concerning the number of accidents which were caused by inappropriate behavior of people involved in the system and its environment, including their results. Selectesd results of dangerous events have been shown in Tables: 2,3 and 4.

Table 1

Description of the algorithm blocks

1	Determine a set of road events occurred in the analyzed time interval Zi; i = {1, 2, 3, . . . , k}.
2	Choose an event significant in terms of the analyzed system opearation safety.
3	Order events according to the date of occurrence Z_1, Z_2, Z_3, . . . , Z_k.
4	Choose the firs event for assessment Z_i, i = 1.
5	Choose the next event for assessment Z_i + 1.
A	Was damage to the transport means subsystem the cause of the analyzed event?
B	Was the behavior of people present in the transport means the cause of the event?
C	Was the impact of the environment the cause of the anlyzed event?
6	Make a summary evaluation of the transport system operation safety.
7	Demonstrate the result

Table 2

Numbers of road accidents caused by people present in the transport system and its environment, in the analyzed period of time

The cause od accident	*Number of road accodents*							
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
The vehicle driver	44835	42860	43066	41370	3794	39 730	37 129	38 434
sidewalker	3072	2791	3640	3285	8041	7 119	6 719	6 912
The vehicle passenger	144	128	124	126	119	127	–	–

Table 3

The number of people killed in car accidents which were caused by people present in the transport system and its environment, in the analyzed period of time

The cause Accident	*Number of people killed in accidents*							
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
The vehicle driver	4 650	4 262	4 470	4 382	4 232	4 239	3 729	3 753
Sidewalker	1 275	1 006	1 098	1 017	838	979	1007	1105
The vehicle passenger	25	18	13	8	13	11	–	–

Table 4

The number of people injured in road accidents caused by people present in the transport system and its environment, in the analyzed period of time

Accidenthe causet	***Number of injured people***							
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Driver	59 970	57 799	57 670	54 835	51 024	53 429	49 784	52 240
Sidewalker	2677	3493	4240	2916	5 657	6 363	5 828	5 946
The vehicle passenger	127	119	116	129	109	124	–	–

For an assessment of the undesirable impact of particular groups of people present in the road transport system and its environment, the following set of indexes has been specified and these indexes can make up components describing the system opearation safety in the general assessment model.

Number of road accidents caused by people who drive the vehicles, falling on 100 road accidents

$$W_1 = \frac{L_{WK} \cdot 100}{L_W} \tag{7}$$

where:

L_W – number of all occurred road events in the analyzed period of time

L_{WK} – Number of road accidents caused by the vehicle drivers in the analysed period of time.

Number of road accidents caused by sidewalkers, falling on 100 accidents.

$$W_2 = \frac{L_{WP} \cdot 100}{L_W} \tag{8}$$

where

L_{WP} – number of road accidents caused by sidewalkers in the analyzed period of time.

Number of road accidents caused by passengers using transport means, falling on 100 road accidents.

$$W_3 = \frac{L_{WPA} \cdot 100}{L_W} \tag{9}$$

where:

L_{WPA} – number of road accidents caused by passengers using transport means in the analyzed period of time.

Number of people killed in road accidents caused by the vehicle drivers, falling on 100 road accidents.

$$W_4 = \frac{L_{ZK} \cdot 100}{L_{WK}} \tag{10}$$

where:

L_{ZK} – number of people killed in accidents caused by the drivers of vehicles.

Number of people killed in road accidents caused by sidewalkers.

$$W_5 = \frac{L_{ZP} \cdot 100}{L_{WP}} \tag{11}$$

where:

L_{ZP} – number of people killed in road accidents caused by passengers using transport means.

Number of people killed in accidents caused by passengers using transport means falling on 100 accidents.

$$W_6 = \frac{L_{ZPA} \cdot 100}{L_{WPA}} \tag{12}$$

where :

L_{ZK} – number of people killed in road accidents caused by passengers using transport means.

Having in mind a complex assessment of the transport system operation quality, the above indexes make up components X of a multidimensional vector of quality in terms of the influence exerted by peoples' behaviors on its operation safety, and they are accounted for in the resultant assessment model.

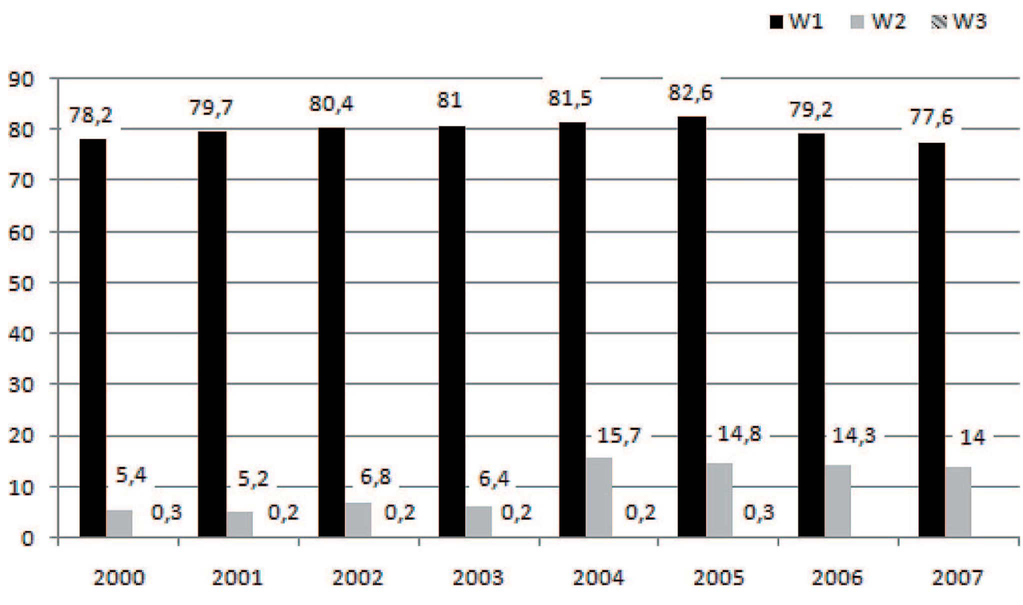

Fig. 6. Values of indexws W1,W2,W3 in the analyzed period of time

The analysis of data presented in figures 6 and 7 proves that about 80 out of 100 road accidents were caused by inappropriate actions of the drivers (value of index W). This tendency is sustained at the same level in the analyzed period of

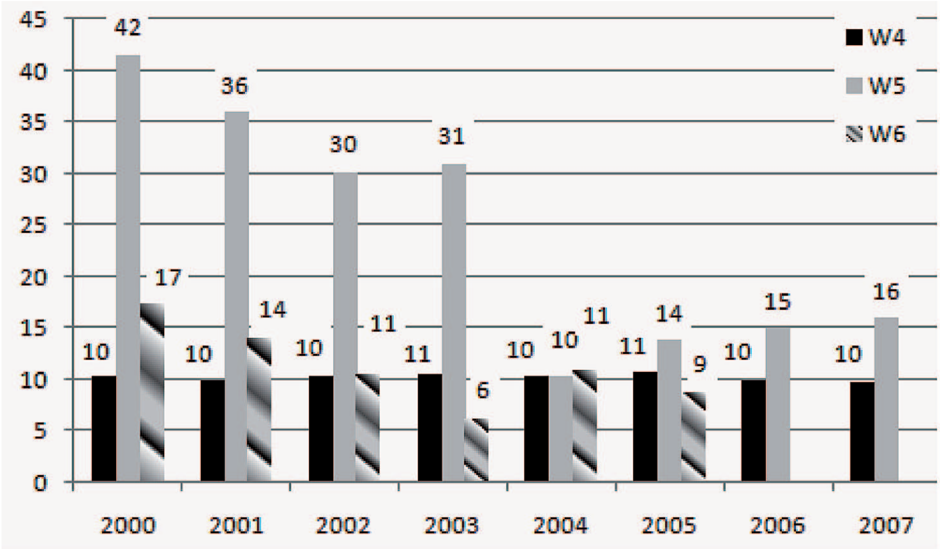

Fig. 7. Values of indexes W4,W5,W6 in the analyzed period of time

time like in case of W index, whereas, in case of W2 index there can be seen a significant increase in the index value, in the successive years of the analyzed period of time. In order to obtain the resultant assessment of carried out transports safety, as the main assessment criterion of the analyzed transport system operation quality, there should be made an optimization of indexes used in the model mathematical description.

6. Conclusions

The discussed concept of operation quality assessment of complex transport systems can be applied both for an assessment of the same system operation quality in different times, different systems in the same time and also different systems in different times with the assumption that the assessment is being made on the basis of the same criteria and their features distinguished for the object research. Providing the carried out transports with a high level of safety is of primary importance for the evaluation of the transport task quality. However, in order to make a detailed assessment of the system operation quality, research on the level of reliability, serviceability, ergonomics and its operation efficiency must be performed.

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