Influence of human factor on transport system safety

Piotr Bojar, Łukasz Muślewski, Maciej Woropay, Janusz Szpytko

Abstract: Road transport systems are socio-technical systems of the type Human - Technical object - Environment (H-TO-E). In these systems hazards can be caused by: the man C, the technical object OT, and influence of the environment on the technical object and people who are present in the system and its environment. The authors of the paper make an attempt to evaluate the level of threats resulting from intended or not intended actions of people situated in this environment.

Keywords: Human engineering system, safety operation.

I. INTRODUCTION

Transport systems are examples of socio-technical systems in which direct realization of their tasks is performed by operational subsystems of the type Man - Technical Object (operator - transport means) performing tasks within the system environment. Moreover, a man can be involved in transport systems:
- inside the transport means (passenger),
- within the transport means environment (other drivers, pedestrians etc.).

Because of the man involved in the transport system, the most important criterion for assessment of the realized transports is their operational safety.

Operational safety of a transport system in which values of the distinguished features describing the system in a given period of time \( t \in [t_0, t_1] \) are contained within established boundaries, with defined levels of actions of forcing factors. These factors can be divided into \([1, 2, 6, 7]\):
- operational - within the system-forcing factors affecting the means of transport as a result of the transport task realization,
- external - forcing factors characterizing the influence of the environment on the means of transport (not conditioned by its operation),
- antropotechnical - forcing factors affecting an elementary operational subsystem as a result of human activities, for example due to an operator’s mistake, improper behaviors of passengers or pedestrians.

Because of a different placement of the man in the transport system and his/her safety it is necessary to develop a method which will account for the effect of forcing antropotechnical factors on the system operational safety.

II. AIM OF THE PAPER

The aim of this work is to assess the level of undesirable influence of people situated in the road transport systems and their environment on the operational safety of these systems.

III. OBJECT AND SUBJECT OF EXAMINATIONS

The objects of investigations are general road transport systems realizing transport tasks all over Poland. The subject of investigations is an analysis of undesirable behaviors of people and their influence on the safety change levels of the system operation.

IV. DEVELOPING AN ALGORITHM OF ASSESSMENT OF INFLUENCE OF BEHAVIORs OF PEOPLE SITUATED IN ROAD TRANSPORT SYSTEMS AND ITS ENVIRONMENT ON THE TRANSPORT SYSTEM OPERATION

Safety level at a given time can be represented by a vector which ends in point \( M (x_1(t), x_2(t), x_3(t), ..., x_n(t)) \) in \( n \)-th dimensional space. Figure 1 shows safety level of the system performance at time \( t \) in 3-dimensional spaces. Point \( M \) in diagram 2 marks standard level of safety for the system. Boundary values of the characteristics \( \{x_1, y_1, z_1\} \) determine allowable changes ranges of the safety level for given characteristics. In 3-d they form a cube of allowable safety level variations. Point \( M_1 \) (fig 3) represents the level of safe performance within the limits of allowable hazards level. Characteristics exceeding limit values endangers safe performance (disallowable hazards level), points \( M_2 \) and \( M_3 \).
Taking into account above hazards, the performance of the system is in state of limited fit for use down to its damages of key elements. Such state consists of different safety levels depending on the significance of damaged element and the level of damage.

Possible results of such state are:
- injury or death of road transport users,
- damage to means of transport,
- financial damages to surrounding environment (damage to properties, telecommunication network, electrical infrastructure, forestry etc.).

For this reason safe transport system performance criterion should apply to its individual elements and their functions in that system:

1. Means of transport requirements:
   - high safety performance level,
   - high resistance,
   - high reliability;
2. Environmental requirements for road transport system:
   - correct design of road infrastructure,
   - proper road coverage in good condition,
   - meteorological conditions allowing safe realizations of transport task;
3. Operating staff requirements:
   - appropriate qualifications,
   - approved health conditions,
   - good stress tolerance level,
   - good reflexes.

Above requirements are the criterions for safe performance of the road transport system. They can be described by a set of indicators.

A man in a transport system can be situated inside a vehicle as: a driver, passenger and in the system environment as a pedestrian, cyclist, etc. In relation to this, threats in the transport system caused by undesirable actions of people depend on their placement in the transport system [4].

In order to make an assessment of the influence of undesirable behaviors of people on the operational safety of the transport system, an algorithm of this safety assessment, which was presented in fig.2, has been built; description of particular blocks of the algorithm has been presented in table 1.

V. ROAD TRAFFIC SAFETY EXAMINATIONS AND THEIR SELECTED RESULTS

The examinations involved gathering information on the number of road accidents which were caused by improper actions of people situated inside the transport means system and its environment and the effects of these events. Relevant data was obtained from the Main Police Station and referred to 01.01.2000 to 31.12.2007. The obtained data has been demonstrated in tables 2 ÷ 4.

<table>
<thead>
<tr>
<th>No</th>
<th>Name of blocks of algorithm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Determine a set of road events occurred in the analyzed time period $Z_i; i = {1,2,3,..., k}$.</td>
</tr>
<tr>
<td>2</td>
<td>Chose events significant in terms of operational safety of the analyzed system.</td>
</tr>
<tr>
<td>3</td>
<td>Order the events according to their occurrence $Z_1, Z_2, Z_3, ... , Z_k$.</td>
</tr>
<tr>
<td>4</td>
<td>Choose for assessment the first event $Z_i; i = 1$.</td>
</tr>
<tr>
<td>5</td>
<td>Choose for assessment the next road event $Z_{i+1}$.</td>
</tr>
<tr>
<td>C</td>
<td>Was behavior of people situated in the transport system and its environment the cause of an analyzed event?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year of accidents</th>
<th>Driver of vehicle</th>
<th>Pedestrian</th>
<th>Passenger</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>44835</td>
<td>3072</td>
<td>144</td>
</tr>
<tr>
<td>2001</td>
<td>42860</td>
<td>2791</td>
<td>128</td>
</tr>
<tr>
<td>2002</td>
<td>43066</td>
<td>3640</td>
<td>124</td>
</tr>
<tr>
<td>2003</td>
<td>41370</td>
<td>3285</td>
<td>126</td>
</tr>
</tbody>
</table>
For evaluation of the level of the influence of undesirable actions of particular groups of people situated in the transport system or its environment the following set of indicators has been chosen:

The number of road accidents caused by the vehicle drivers falling on 100 road accidents:

$$W_1 = \frac{L_{WK} \cdot 100}{L_W}$$  \hspace{1cm} (1)$$

where:

- $L_W$ – number of all road accidents caused by drivers in the analyzed time period
- $L_{WK}$ – numbers of road events caused by drivers

The number of road accidents caused by pedestrians falling on 100 accidents:

$$W_2 = \frac{L_{WP} \cdot 100}{L_W}$$  \hspace{1cm} (2)$$

where:

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

The number of road accidents caused by passengers using means of transport falling on 100 road accidents:

$$W_3 = \frac{L_{WP4} \cdot 100}{L_W}$$  \hspace{1cm} (3)$$

where:

- $L_{WP4}$ – number of road accidents caused by passengers using means of transport falling on 100 road accidents in the analyzed time period

The number of road accidents caused by other drivers falling on 100 road accidents:

$$W_4 = \frac{L_{ZK} \cdot 100}{L_{WK}}$$  \hspace{1cm} (4)$$

where:

- $L_{ZK}$ – number of people killed in road accidents caused by drivers of vehicles in the analyzed time period falling on 100 road accidents.

The number of people killed in road accidents caused by drivers of vehicles falling on 100 road accidents:

$$W_5 = \frac{L_{ZP} \cdot 100}{L_{WP}}$$  \hspace{1cm} (5)$$

where:

- $L_{ZP}$ – number of people killed in road accidents caused by pedestrians, in the analyzed time period falling on 100 road accidents.

The number of killed people in road accidents caused by passengers using the means of transport in the analyzed time period:

$$W_6 = \frac{L_{ZPA} \cdot 100}{L_{WP4}}$$  \hspace{1cm} (6)$$

where:

- $L_{ZPA}$ – number of people killed in road accidents caused by passengers using the means of transport in the analyzed time period.

VI. SELECTED RESULTS OF EXAMINATIONS

Results of safety examinations in road transport systems in the analyzed time period are demonstrated in table 5. They show that for every 100 road accidents 80 were caused by improper behaviors of drivers (value of indicator W) This tendency is of constant character in the analyzed time period like in the case of indicator W3, whereas in case of indicator W2 significant rise of this indicator value in the successive years of the analyzed time period can be observed.

！Table III

<table>
<thead>
<tr>
<th>Year of accidents</th>
<th>Perpetrator of accident</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>driver of vehicle</td>
</tr>
<tr>
<td>2000</td>
<td>4650</td>
</tr>
<tr>
<td>2001</td>
<td>4262</td>
</tr>
<tr>
<td>2002</td>
<td>4470</td>
</tr>
<tr>
<td>2003</td>
<td>4382</td>
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</table>

！Table IV

<table>
<thead>
<tr>
<th>Year of accidents</th>
<th>Perpetrator of accident</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>driver of vehicle</td>
</tr>
<tr>
<td>2000</td>
<td>59970</td>
</tr>
<tr>
<td>2001</td>
<td>57799</td>
</tr>
<tr>
<td>2002</td>
<td>57670</td>
</tr>
<tr>
<td>2003</td>
<td>54835</td>
</tr>
</tbody>
</table>
In table 5 also values of indicators of the number of killed persons in result of road accidents caused by different groups of people situated in the transport system and its environment have been presented.

**VII. ANALYSIS OF RESULTS AND CONCLUSIONS**

From the data obtained from the examinations it results that for every 100 road accidents caused by the vehicle drivers (indicator W) in the analyzed time period 10 persons were dead, the indicator remained on this level in particular years. As for Wd indicator, its value drop by 74% was observed being followed by its rise until 2004.

Similar changes have been noted for indicator W6 in which case a triple drop of its value can be noticed in 2003 and then, its renew rise, unfortunately a full analysis of this indicator value changes is not possible throughout the analyzed time due to the lack of data on the number of accidents and fatalities being the effect of improper behavior of means of transport passengers.

The rise of values of the analyzed indicators in 2004 is caused by an increase in traffic intensity resulting from an increasing number of vehicles on the roads.

There is a necessity of conducting further investigations aiming at identification of the most frequent reasons of improper behaviors of particular groups of people situated in transport systems in order to increase security level of the systems operation.

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**REFERENCES**


**Piotr Bojar** was born in Brodnica in Poland in 23-09-1978. PhD Eng. of Maintenance of Machines and Vehicles, University of Technology and Life Science in Bydgoszcz, Poland, 2009. M.Sc. Eng. of Maintenance of Machines and Vehicles, University of Technology and Live science in Bydgoszcz, Poland, 2003. He’s work in Department of Transport in Institute of Maintenance of machines and Transport, University of Technology and Life Science in Bydgoszcz.

Chosen publications:
- Woropay M., Bojar P.: Diagnosis operational safety of a transport system. Problemy Transportu, Tom 4 Zeszyt 3 część II. Wydawnictwo politechniki Śpiskiej Gliwice 2009

In his research he deals with analysis and assessment of operational safety of real means of road transport. PhD Eng. Bojar is a member of Polish Society of Mechanic Engineers (SIMP).

**Łukasz Muślewski** was born in Bydgoszcz in Poland in 02-06-1973. PhD Eng. of Maintenance of Machines and Vehicles, ITWL in Warsaw, Poland, 2004. M.Sc. Eng. of Maintenance of Machines and Vehicles, University of Technology and Live science in Bydgoszcz, Poland, 1998. He is employed in J.J Śniadeckich University of Technology and Life Sciences in Bydgoszcz, Faculty of Mechanical Engineering. He is involved in research on operation quality of complex exploitation systems, especially transport ones. The research includes: the systems safety, reliability, efficiency, functionality, and their impact on the environment.

Chosen publications:
Maciej Woropay was born in Gdańsk on 01.04.1940. Prof. of technical sciences, 2005. PhD Eng. of Maintenance of machines, Department of machines and vehicles, University of Technology in Poznan, Poland, 1976. M.Sc. Eng. Department of Mechanics and Technology, University of Technology in Gdańsk, Poland, 1965. His work in Department of Maintenance in Institute of Maintenance of machines and Transport, University of Technology and Life Science in Bydgoszcz.

1995-2009 was the head of the Machine Maintenance Department at the Mechanical Engineering Faculty of the University of Technology and Life Sciences in Bydgoszcz.

Chosen publications:
- Woropay M., Muślewski Ł.: Quality as a system on example of transport system. Journal of KONES Internal Combustion Engines, Warszawa, 2004

In his research he deals with problems connected with theory of systems, theory of reliability and safety, and maintenance process control in complex biotechnical systems, especially with control of these processes in real transport systems.

Prof. Dr. hab. C.Eng. Janusz Szpytko, AGH University of Science and Technology, Faculty of Mechanical Engineering and Robotics. Specialist in designing and exploitation of transport systems and devices, electronics, safety and reliability, monitoring and diagnostics, decision making systems, telematics. Author or co-author of app. 400 publications, both in Polish and English. Member of: STST KT PAN, TC IFAC, SEFI, ISPE, PTD, PTB, PSRA, ISA, SITPH and others. Visiting professor at the universities in: UK, France, Canada, Italy, Greece, Canada, Laos. Coordinator and member of several R&D projects both national and international. Organizer and member of several scientific and programme committees of international and national conferences and symposiums.