Maciej WOROPAY*, Piotr BOJAR
University of Technology and Life Sciences in Bydgoszcz, Faculty of Mechanical Engineering
ul. Kaliskiego 7, 85 – 789 Bydgoszcz, Poland
**Corresponding author*. E-mail: kem@utp.edu.pl

DIAGNOSIS OPERATIONAL SAFETY OF A TRANSPORT SYSTEM

Summary. The transport systems are sociotechnical systems in which the direct realization of the tasks is dealt with by an executive subsystem consisting of the elementary subsystems of a human – a technical object (an operator – a means of transport) type realizing the tasks within the system environment. In respect of a human located within a transport system the most significant criterion in the evaluation of transport being realized is their safety.

The safety level of the task realization is influenced by the risks resulting from the interaction of the forcing factors, affecting an elementary executive subsystem.

These factors may be divided into [8]:
- working;
- external;
- antropotechnical.

Due to the complexity of the systems being analysed in the paper, it has been attempted to evaluate the influence of the forcing factors on the safety of this system operation.

DIAGNOZOWANIE BEZPIECZEŃSTWA DZIAŁANIA SYSTEMU TRANSPORTOWEGO

Streszczenie. Systemy transportowe są systemami socjotechnicznymi, w których bezpośrednią realizacją zadań zajmuje się podsystem wykonawczy złożony z podsystemów elementarnych typu człowiek – obiekt techniczny (operator – środek transportu) realizujących zadania w otoczeniu systemu. Ze względu na człowieka umiejscowionego w systemie transportowym najistotniejszym kryterium w ocenie realizowanych przewozów jest ich bezpieczeństwo.

Na poziom bezpieczeństwa realizacji zadań wpływają zagrożenia wynikające z oddziaływania czynników wymuszających, oddziałujących na elementarny podsystem wykonawczy.

Czynniki te można podzielić na [8]:
- robocze;
- zewnętrzne;
- antropotechniczne.

Ze względu na złożoność analizowanych systemów w pracy podjęto próbę oceny wpływu oddziaływań czynników wymuszających na bezpieczeństwo działania tego systemu.

1. INTRODUCTION

Transport systems are the systems of which is the aim to realize transports over the determined area, using the means of transport. The essential requirements regarding the transport systems are:

- transportation safety,
- means of transport reliability,
- transportation punctuality,
- transportation adequate frequency,
- adequate standard of the services provided.

The transport systems are an example of the sociotechnical systems of a Human – a Technical Object – an Environment <H – TO – E> type in which the direct realization of the system tasks is dealt with by an executive subsystem consisting of the elementary subsystems of a human – a technical object (an operator – a means of transport) type realizing the tasks within the system environment. Moreover, a human within the transport system may be located:

- inside the means of transport (a passenger),
- within the means of transport environment, other drivers, pedestrians, etc.

In respect of a human located within a transport system ***the most significant criterion in the evaluation of the transports being realized is safety***.

Operational safety of a transport system in which values of the distinguished features describing the system in a given period of time t, $t \subset [t_0,\ t_k]$ are contained within established boundaries, with defined levels of actions of forcing factors.

Safety level at a given time can be represented by a vector which ends in point M ($x_1(t)$, $x_2(t)$, $x_3(t)$, ..., $x_k(t)$) in n-dimensional space. Figure 1 shows safety level of the system performance at time t in 3-dimentional space. 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 i M_3.

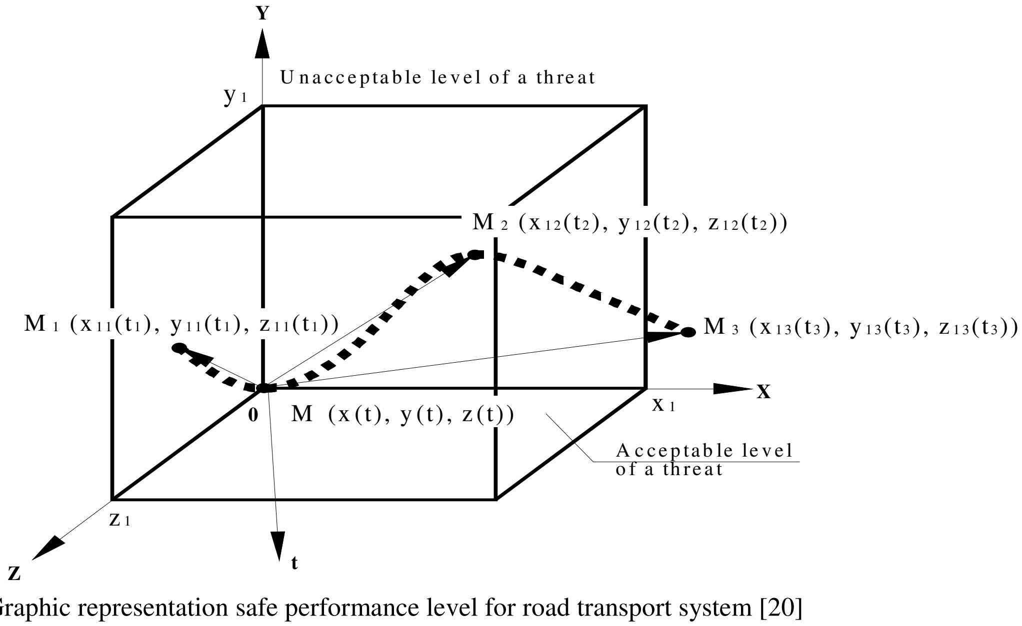

Fig. 1. Graphic representation safe performance level for road transport system [20]
Rys. 1. Graficzna interpretacja stanu bezpiecznego działania systemu transportu drogowego [20]

The safety level of the task realization is influenced by the risks resulting from the interaction of the forcing factors, affecting an elementary executive subsystem.

These factors may be divided into [8]:

- ***working*** (within a system) – forcing factors affecting a means of transport as a result of realization of the usable functions,
- ***external*** - forcing factors being characteristic for interaction of the environment affecting a means of transport (not depending on its functioning),
- ***antropotechnical*** - forcing factors affecting a means of transport as a result of human actions, e.g. due to an operator's faults.

The authors of the works regarding safety of the transport systems and safety of a road traffic, e.g.: [4, 5, 6, 7] evaluate the safety level of the road traffic on the basis of the databases provided by the police. These bases include data regarding the number of road accidents which occurred within the time interval under analysis and number of fatalities and injured people resulting from the accidents occurred.

The essential source document of the accident registration system is a road events card which is filled in by the Police officers at the event site, according to their subjective judgment of the course and accompanying circumstances.

It should be noted that due to lack of diagnostic measures and no time, the state of a vehicle is not evaluated after a road event, therefore the Police reports mostly provide inappropriate driver's actions, such as (overspeeding, driving speed not adjusted to the existing road conditions etc.) as the most frequent cause of a road event.

A road event is a complex phenomenon which may result from the interaction of the aforementioned forcing factors: *working (resulting from a vehicle serviceability condition), external (resulting from the environmental interaction) and antropotechnical (being a result of faults of a driver and people located in the system and within its environment).*

When analysing the causes of the road accidents occurrence they should be treated as independent events which may occur individually or jointly, as shown in the table No. 1.

Table 1

Possible sequences of events leading to a road accident occurrence

Pos.	Working factors interaction	External factors interaction	Antropotechnical factors interaction
1	**1**	1	1
2	**1**	0	1
3	**1**	1	0
4	**1**	0	0
5	0	1	1
6	0	1	0
7	0	0	1
8	0	0	0

The table represents sequences of the events leading to the risk states of a transport system safety, where:

1 – an event in which interaction of the chosen forcing factors had an influence on the road event occurrence,

0 – an event in which interaction of the chosen forcing factors had no influence on the road event occurrence.

The risk state of the system safety No. 8 is an abstract state, the occurrence of which was affected by none of the system elements.

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

2. OBJECT OF THE STUDY

The object of the study is a generally defined transport system being a sociotechnical system of a *Human – a Technical Object – an Environment* <*H – TO – E*> type, the main task of which is to transport people safely within the determined quantitative and territorial range, using the means of transport being operated and maintained inside this system.

The system under investigation is included in the class of the complex real systems, performing their tasks in the defined environment [8, 9, 10, 11].

A complex system is such a system which includes sets of elements that can in turn be also complex systems interlinked by their functions and subordinated to the realization of the assigned tasks [12, 15].

An element (an elementary subsystem) is called such a system in which it is impossible to distinguish the subsystems of a lower level [14].

The complexity of a system depends both on the number of its subsystems, located on different decomposition levels, and the number of these levels.

The location of each subsystem in the system structure and its operation aim are to be taken into account when performing investigations of the system.

The subsystems located on the successive decomposition levels may be treated as indivisible objects, depending on the problem consideration circumstantiality.

The features of the system as a whole are determined not only on the basis of the features of its individual subsystems, but also on the basis of its structure.

An example of such a transport type system is a collective urban transport system. The transportation inside an urban transport system may be performed using different means of transport. The most popular, however, is a bus transport system.

The following subsystems may be distinguished on the individual decomposition levels (Fig. 2):

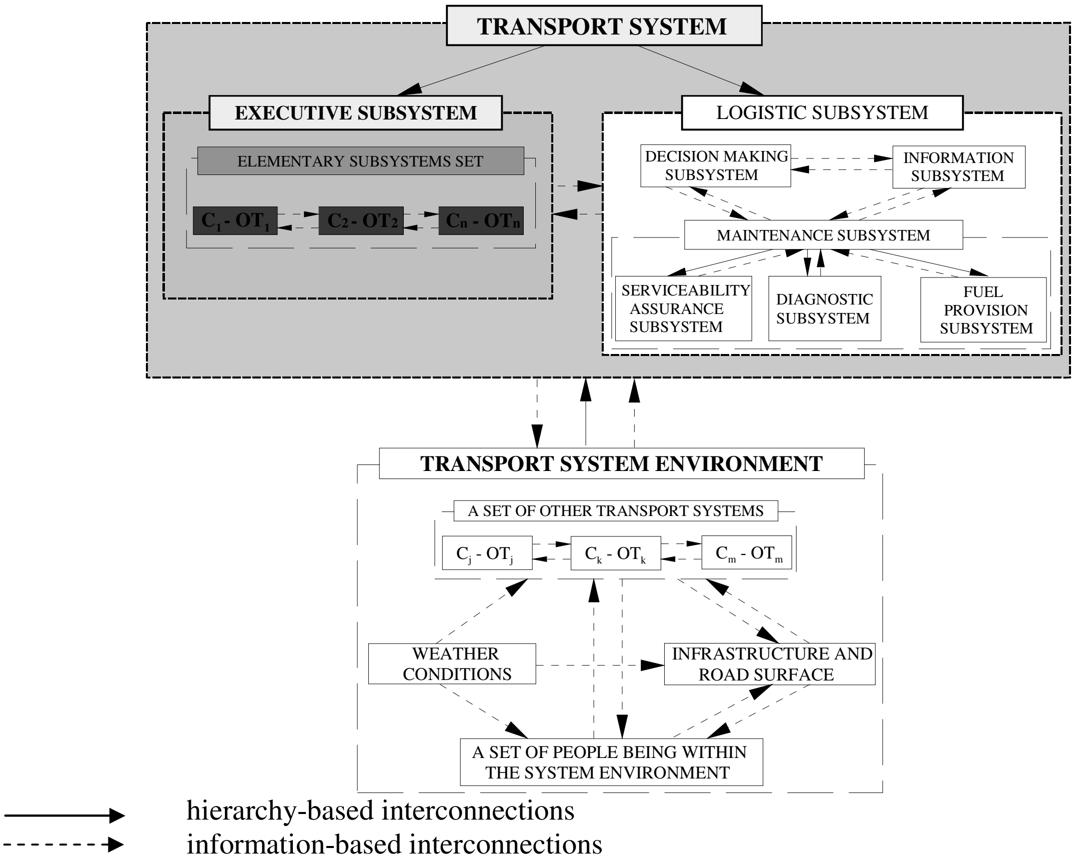

Fig. 2. Means of transport operation and maintenance system model
Rys. 2. Model systemu eksploatacji środków transportu

As it results from the above diagram, a human inside a transport system under analysis may be located inside the system (a bus driver or a passenger), as well as he/she may be located within the system environment (other vehicle drivers, bikers, pedestrians).

Due to differentiated location of a human and his/her safety, there is a need to build a method which would comprehensively include the forcing factors affecting this system safety operation.

3. AIM OF THE STUDY

The aim of the study is to build an algorithm to evaluate the forcing factors affecting the road transport system operation safety.

4. ALGORITHM TO EVALUATE TRANSPORT SYSTEM OPERATION SAFETY

The algorithm presented in the figure 3 reflects the operational procedure used when evaluating the road transport operation safety, taking into account the major forcing factors described herein.

Three essential members A, B and C may be distinguished in this algorithm, they are related to:

A – evaluation of the means of transport operation safety ,
B – evaluation of the interaction of the system environment affecting the operation safety of that system,

C – evaluation of the interaction of humans located inside the system and within its environment affecting the operation safety of that system.

The individual members of the algorithm may form separate algorithms to evaluate interaction of the forcing factors affecting the operation safety of the system under analysis. When combined they constitute a comprehensive evaluation of the transport system operation safety.

In terms of the algorithm complexity the individual blocks have been presented in a simplified form using a symbolic description, all the symbols have been explained in the table 2.

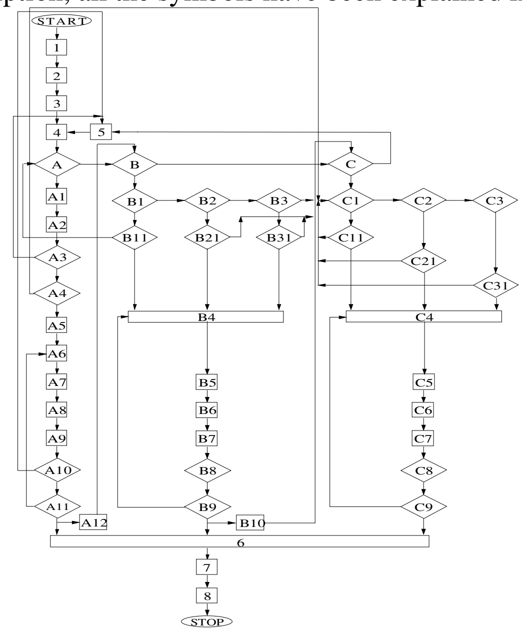

Fig. 3. Algorithm to evaluate the transport system operation safety
Rys. 3. Algorytm oceny bezpieczeństwa działania systemu transportowego

Table 2

Description of the algorithm to evaluate the transport system operation safety

Block code	Code description
1	Determine a set of the road events occurred within the analysed time interval Zi; i = {1, 2, 3, …, k}.
2	Select the events being significant from the point of view of the system operation safety being analysed.
3	Arrange in series the events according to their occurrence date $Z_1, Z_2, Z_3, \ldots, Z_k$.
4	Select the first event to be evaluated Z_i, i = 1.
5	Select another toad event to be analysed $Z_i + 1$.
6	Make collective evaluation of the transport system operation safety
7	Evaluate the costs due to the events occurred
8	Show the result
A	Did a damage to a subsystem of a means of transport cause the occurrence of the event under analysis ?
A1	Determine the criteria to evaluate the significance of the damaged subsystem.
A2	Evaluate the significance of the damaged subsystem.
A3	Is the damaged subsystem significant from the point of view of the means of transport operation safety?
A4	Did the damage to the significant subsystem affected the improper operator's actions?
A5	Evaluate the change level to the means of transport serviceability state as a result of the damage to the analysed subsystem.

cont. table 2

A6	Determine a set of indices to evaluate the means of transport operation safety.
A7	Determine the criteria to evaluate the means of transport operation safety.
A8	Determine the set of indices being representative for the evaluation of the means of transport operation safety.
A9	Evaluate safety of the means of transport operation.
A10	Is the analysed event $Z_i = Z_k$? where i = {1, 2, 3, …, k}
A11	Is the resultant model adequate?
A12	Check if the event B occurred as well.
B	Did the interactions of the environment cause the occurrence of the analysed event?
B1	Did the improper state of the pavement surface cause the occurrence of the analysed event?
B11	Did the improper state of the pavement surface cause a damage to the means of transport?
B2	Did the improper road infrastructure cause the occurrence of the event?
B21	Did the improper road infrastructure cause improper actions of the people located within the system and within its environment?
B3	Did the weather conditions cause the occurrence of the event?
B4	Determine a set of the indices to evaluate safe interaction of the environment affecting people and means of transport.
B5	Determine criteria to evaluate safe interaction of the environment affecting people and means of transport.
B6	Determine a set of the indices representative for evaluation of the safe interaction of the environment affecting people and means of transport.
B7	Evaluate safe interaction of the environment affecting people and means of transport.
B8	Is the analysed event Zi = Zk? where i = {1, 2, 3, …, k}
B9	Is the resultant model adequate?
B10	Check if the event C occurred as well.
C	Did the actions of the people located inside the means of transport and within its environment cause the occurrence of the event?
C1	Did the improper driver's actions cause the occurrence of the event?
C11	Did the improper driver's actions cause a damage to the means of transport subsystem?
C2	Did the improper actions of the means of transport passengers cause the occurrence of the event?
C21	Did the improper actions of the passengers affect the wrong driver's actions?
C3	Did the improper actions of the people located within the environment of the means of transport cause the occurrence of the event?
C31	Did the improper actions of the people located within the environment of the means of transport affect the wrong driver's actions?
C4	Determine a set of the indices to evaluate undesirable interactions of the people located inside the means of transport and within its environment.
C5	Determine the evaluation criteria of the safe interactions of the people located inside the means of transport and within its environment.
C6	Determine a set of the indices representative for evaluation of the interactions of the people located inside the means of transport and within its environment.
C7	Evaluate safe interaction of the people located inside the means of transport and within its environment.
C8	Is the analysed event Zi = Zk gdzie, i = {1, 2, ..., k}
C9	Is the resultant model adequate?

5. CONCLUSIONS

The method to analyse safety of the transport system operation safety suggested herein is an innovative approach of the road transport system safety evaluation.

- The method is a universal one and it may be applied to evaluate operation safety of various types of road transport systems.

- The components of the algorithm may constitute separate methods to evaluate interactions of the individual forcing factors affecting the safety level of the system operation under analysis.
- There is a necessity to continue further analysis of the problem described herein, in order to show precisely all the relations taking place between the individual elements of the system under analysis.

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