EFECTIVENESS AND SAFETY OF COMPLEX TRANSPORT SYSTEMS

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Summary. Analysis of transport systems effectiveness is based on the safety of ergatic systems, the functionality of which is based on and supported by the mutual influence of a man – operator and technical transport means. The need to increase the level of transport safety in different time, space and climate conditions creates the need to widen the transport means functions not only in the area of physical principles but also in the way of their use. Transport systems functions devoted to their practical applicability and the adjustment of the man – operator form specialised ergatic complexes, the errors of which the operator controlling functions removes. Specialised complexes with determined scale of use then determine operational safety and effectiveness. The following notions, which present the inputs to their analysis are important in the analysis of ergatic systems effectiveness and safety.

Keywords: ergatic system, effectiveness, ergonomic and economic factor, polyergatic complex, safety, reliability.

1. INTRODUCTION

For many transport systems the costs for widening transport infrastructure are too high. Therefore it is required to look for the effectiveness of transport quality improvement within existing infrastructure. It is necessary to search for new methods of research in dichotomic states (success and failure) of intelligent transport systems integrated into poly-ergatic systems [4]. New trends reflect the degrees of aimed effectiveness of meta-principles which are the criterion of development taking into account the degrees of freedom of different types of transport means. The solution is possible through exemplary development of intelligent transport systems technology covering non-trivial physical distances. Principally, those accept the mutuality of the distribution of artificial or natural aims, which are the information source for the control of a particular transport means by a man - operator. It means that the subjects of transport systems include transport means and people, who control them. Together they create mutuality connected with the limits of transport means safety [1].

Transport complexes possess limited scale of usability, which is also limited also by operational safety and effectiveness. The following notions which present the inputs into their analysis are important in the analysis of ergatic systems effectiveness and safety. From the viewpoint of systematic approach it is a method which is typical for complex polyergatic systems: people – transport means.

Fig. 1 shows transport systems specialisation from the point of view of their control by a man, and it also justifies the notion of an ergatic complex, i.e. a system controlled according to errors. The figure also explains similarity of systems in transport complexes necessary for solving reliability.

Figure. 1 Intelligent transport systems in the cockpits of transport means
Legend: board information system: a) train; b) car; c) aircraft; d) ship

2. QUANTITATIVE CRITERIA OF POLYERGATIC TRANSPORT SYSTEMS EFFECTIVENESS ESTIMATION

Field of action of transport, as a part of civilised developed society, is evaluated also by displayed safety, controllability and economics [3]. Transport systems safety is a complex criterion, according to which it is possible to evaluate the reliability of functions not only of transport means, but also personnel. From the stated point of view, ergatic safety must be controlled and controllable by social environment and is realised in production and professional preparation of transport participants. Transport safety is a notion, which does not have adequate mathematical model as it is connected with undefinable characteristics of a person, in which it reflects [3].
Quantitative estimations of transport safety and measures manifestation for the increase of their effectiveness are performed with the help of multi-layered absolute and relative evaluations [2] [3], from which the following can be earmarked [1]:

1) Mean time of accident number connected with one particular period.
2) Number of accidents, to which occurrence of presumptions for accidents is allocated.
3) Number of paasenger-kilometers belonging to one transport accident.
4) Probability of the demonstration of occurred reason, which caused the accident and the rate of its demonstration.
5) Conditions for the creation of accident probability as well as unconditional creation of the accident evoked by a certain reason.
6) Total rate of unconditional probability evoked by all reasons for observed type of transport.

Analysis method of the above mentioned criteria is performed by statistic methods which are suitable also for the creation of relevant safety development prognosis creation. As it follows from the above stated criteria, transport safety is influenced by many factors and therefore it is necessary to determine basic variant – mode: transport without catastrophes for the control of safety [7].

3. SYSTEM: PEOPLE – TRANSPORT – MUTUALITY OF TARGET ERGATIC TRANSPORT COMPLEXES

Besides the position of a man – machine, also structured transport infrastructure in its complex potency is included into the stated mutuality. Its set could be estimated as follows [4]:

$$B \geq \{o, t, e, p, t, m, ... x\} \quad (1)$$

where o - transport organisation,
t - technogennic demonstrations,
e - economics,
p - psychological and physiological characteristics of people,
and others, such as moral, ethical and other factors, so-called society civilisation factors, transport means users, which are connected by mutual ties and influence transport quality and safety.

If, for instance, only two factors are selected from the sequence, it is possible to determine their variant mutuality by the following equation:

$$c_n^m = \frac{n!}{(n-m)!\,m!} \quad (2)$$

The equation (2) enables to illustrate the complexity of the problem, when for example the number of factors m = 2 during one observation of followed area can display itself in 650 mutuality's, then:

$$c_{650}^2 = \frac{650\,!}{(650-2)!\,2!} = 210\,925 \quad (3)$$

As it follows from the example, the use of statistic data to express the safety of the influence of each factor is not practically possible and at the same times also the fact that also the transport effectiveness estimation must be performed by probability methods. The unity of safety and effectiveness can be found in the connection of characteristics which express the possibilities (abilities) of each transport complex to adjust to transport conditions [8].

4. SYSTEMIC APPROACH TO THE FORMULATION OF CRITERIA MODEL OF TARGET EFFECTIVENESS OF ERGATIC TRANSPORT COMPLEX

Individual types of transport complexes are getting more and more similar in the sense of their technical equipment, which can be seen in the view of the cockpits of trains, cars, aircrafts, ships, etc. (Fig.1). Without exaggeration it can be stated that the content and aim of every transport ergatic complex, which realises the mutuality of a *man – operator – transport machine*, is navigation. This is the reason why it is suitable to use the notion of navigation ergatic complex (NEC) then, under which a set of elements, including the operator and all usable means to form the image of self-realisation for safe space and time orientation in machine control (cars, aircrafts, ships, etc.) and its position along determined route are understood. The absence of this image means breaking transport rules and a creation of the presumption for a traffic accident [6]. Hence, according to the principles of systemic approach, it is possible to conclude that the role of navigation is in determined limit conditions and determined mode of machine function complying with valid rules and on their base it is possible to realise a set of measures described by events (see [2], [4]) :

$$\frac{B_2}{B_1} \cap B_2 \cap B_4 = A_1 \cap A_2 \cap A_3 \quad (4)$$
$$\left(\frac{B_2}{B_1} \cap B_3 \cap B_4\right) \cap \acute{A}_1 = 0$$

where:
A_1 – probability expressing that navigation systems is working in a reliable way;
A_2 – probability which shows that the NEC systems error under the outer influences can be compensated for by control [4];

A_3 - probability that the operator-pilot decides about the way of NEC error compensation correctly [3];
$\acute{A}_1$ – probability that the transport means does not change its position along the trajectory;
B_1 – transport machine reliability;
B_2 – board navigation complex reliability;
B_3 – operator´s outer navigation complex reliability;
B_4 – reliability of the equipment with the influence on the creation of operator´s creative environment.

The meaning of the equation (3) is illustrated on the display of the element A_2:
If the influence of the reliability of e.g. radio altimeter as a part of NEC on its reliability is considered, it can be found out that the radio altimeter presents the NEC capability limit in the mode of close navigation [8]. It is supposed that under the influence of outer conditions, the radio altimeter would show inaccurate values four times. The errors have accidental character, which can be expressed by the symbol Xi , where i = 1,2,3,4. Let operator – pilot (OP) react to the occurrence of the error correctly with the probability P = 0.5. The occurrence of the accidental event, which will show in the error, has discreet character in each of its displays. The task is to find the distribution of probability of the values of accidental variable X up to the moment of landing [2].
Solution:
It is presumed that OP has ability to compensate for the error with probability $P(A_2) = 0.5$. Let A_{2i} mark the error occurrence in i –times period of approaching flight. Obtained probability (A´ - presents contrary event) can be calculated.
$P(X=0) = P(A'_{21}) = 0.5$
$P(X = 1) = P(A_{21} \cup A'_{22}) = 0.5^2 = 0.25$
$P(X = 2) = P(A_{21} \cup A_{22} \cup A'_{33}) = 0.5^3 = 0.125$
$P(X = 3) = P(A_{21} \cup A_{22} \cup A_{23} \cup A_{24}) = 0.5^4 = 0.0625$
$P(X = 4) = P(A21 \cup A22 \cup A23 \cup A24) = 0.5^4 = 0.0625$

Table 1 Table of resolutions

Xi	0	1	2	3	4
Pi	0.5	0.25	0.125	0.0625	0.0625

Proof:
$$P = \sum_{i=0}^{4} p_i = 1 \quad (5)$$

Practical meaning of the model (3) lies in the fact that it shows the method of securing [6] transport task realisation safety. In further work and research it is possible to devote to another model, which shows the possibility to analyse the structures of navigation ergatic complex operation mode, determination of operability of a part of navigation system and its elements [3] and the option of qualification of effective safety securing.

4. CONCLUSION:

The developing methods of effective securing transport safety. One of the main effects of such a method is the effectiveness of the aim, which enables to increase the reliability of individual transport systems when it is possible to solve immediate information about the transport situation [3] with the help of improved technologies as well as increased growth of operators´ professionalism (skilful control) [4] together with the increased growth of their professional skills.

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