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DEFINING AND ASSESSING THE LEVEL OF RAILWAY TRAFFIC SECURITY

Визначено і показано модель інтерпретації надзвичайних ситуацій як фактора безпеки залізничного руху на прикладі сербських залізниць. Стаття може бути корисна усім, хто цікавиться проблемами безпеки залізничного транспорту.

Определена и показанат модель интерпретации чрезвычайных происшествий как фактора безопасности железнодорожного движения на примере сербских железных дорог. Статья может быть полезна всем тем, кто сталкивается с проблемами безопасности железнодорожного транспорта.

The paper defines and shows a model of interpreting casualty occurrence as a factor of operational safety and risk of the rail traffic. A special emphasis is put on assessing the level of rail traffic safety on the example of the Serbian Railways. The paper may be useful for all those who deal with the tasks of rail traffic safety.

Introduction to the problem

Every kind of traffic is connected with the occurrence of risk which can have grave consequences for the security of people and material resources. The risk increases with the increase of speed at which the traffic operates. Outdated technical means, inadequate organization (regulation and control) of traffic, incomplete knowledge and application of legal and traffic-technical regulations also contribute to the increase of risk.

The safety of railway traffic is further endangered by a number of different emergencies, which are considered to be occurrences that cause at least one of the following consequences: death, serious injury or risk to life, material damage to vehicles, railway lines or goods, as well as interruption of train operation.

The model of defining security of and risk of and risk to traffic in a railway system

The safety of railway traffic is first of all conditioned by reliable and safe train running and performing a variety of traffic-technical operations in which a great number of both different technical means (vehicles, railway lines, signaling and telecommunication means, etc.) and railway staff participate. All these factors are mutually linked in the process of transportation.

Every human error or failure of a device (due to its malfunction, faulty operation or improper use) may break that chain process and cause an emergency (v) which endangers safety (B) due to a risk (U) to traffic in a railway system ($S_{\check{z}s}$), which can be presented by the model shown in fig. 1 and 2.

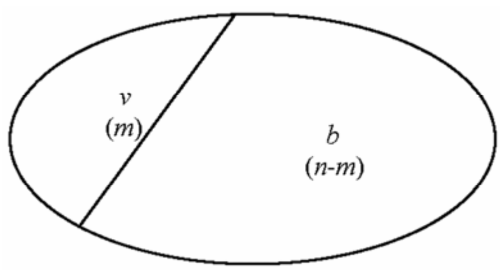

Fig. 1. A set of different occurrences in a railway system

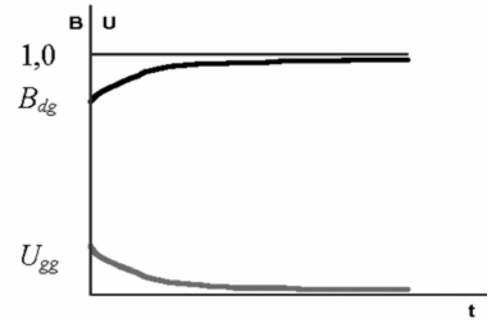

Fig. 2. The interrelation between safety (B_{dg} – the lower limit of the lowest allowed level) and risk (U_{gg} – the upper allowed level of risk) to traffic in which:
v is a subset of emergences, i. e. unsafe state of individual elements of $S_{\check{z}s}$, with corresponding m-cases of unsafe operation b is a sub-group of safe state occurrences of individual elements of $S_{\check{z}s}$, with corresponding ($n - m$) cases of safe state, n being a total number of occurrences (states) in $S_{\check{z}s}$

The probability of risk to security is

$$U = P(\nu) = \frac{m}{n}$$

while the probability of security is

$$P(b)=B=\frac{n-m}{n}=1-\frac{m}{n}=1-U\ .$$

As $B+U=1$, i. e.

$$B=\lim_{\substack{n\to\infty\\ m\to 0}}\frac{n-m}{n}\to 1\ ,$$

It is obvious that the security of traffic is endangered, which leads to the theoretical assumption that security increases with the decrease of risk, and vice versa (fig. 2).

Causes of risk to railway traffic safety

As for the emergencies which endanger the safety of railway traffic system, we can say that those are occurrences which have a mutual cause-and-consequence interrelation. It means that the occurrence of an emergency is conditioned by the existence of a certain cause (U_z) leading to certain consequences (P_o) in certain space and time, which can be shown by the following functional interdependence:

$$P_o=f\left(U_z\right)$$

in which the cause is the independent variable, and the consequence is the dependent variable.

The causes are certain states of insecurity (risk) within the elements of railway system or its surroundings, which at certain points in space and time represent the reason causing the occurrence of an emergency.

According to their major characteristics, the causes of emergencies can be shown in the form of a set of four basic groups of causes

$$U_z=\left\{U_{\check{c}},U_t,U_p,U_o\right\}.$$

$U_{\check{c}}$ – represents a subset of causes referring to the human factor (the so-called «man» factor) which originate from the personal mistakes of workers performing their tasks irregularly and badly within their work, i. e. the working process in railway traffic.

U_t – represents a subset of all technical causes which originate from the condition of railway technical means (tracks, cars, locomotives, signaling, etc.) due to their different technical defects, faults and malfunctions, which belongs to the group of so-called technical factors.

U_p – represents a subset of causes which originate from the transportation items due to the insecure condition of cargo in cars, or the dangerous actions of passengers aboard.

U_o – represents a subset of causes which originate from various harmful influences and effects of surroundings on the elements and components of railway system, such as the so-called natural causes (earthquakes, floods, landslides, extremely high and low temperatures, etc.).

The consequences are harmful changes of condition which occur in certain elements of railway system, caused by the effect of certain factors accompanying emergencies.

According to their character and degree of severity, consequences of emergencies are divided into the following five basic types:

1. Deaths (of passengers, railway workers, and other people) are the consequences with the highest degree of severity.
2. Serious injuries.
3. Slight injuries.
4. Major breakdowns of traffic (disruption of train movements, etc.) expressed by the duration of disruption measured in hours.
5. Material damage (extensive or slight) done to the track, vehicles, goods and other railway installations.

All elements or components of railway traffic system influencing the state of its safety can be called the factors of railway traffic safety.

The basic factors of railway traffic safety are technical means with their technical and functional possibilities (technical factor), and workers who participate directly in railway traffic operation (human factor). The other factors referring to the effects of surroundings and transportation items may also have an important influence on railway traffic safety.

Assessing the level of railway traffic security

The traffic is endangered if there are risks to its functioning, if people's lives are in danger, and if there is damage to goods and railway technical means, which leads to the occurrence of an emergency.

The assessment of railway traffic safety level may be expressed by a certain set of safety parameters in railway exploitation; however, we are going to mention only some of them.

The basic assessment of traffic safety level may be expressed by a probability of emergency occurrence in train operation as

$$P_{uv}=\frac{1}{S_v}$$

and should be as low as possible.

S_v (10^6 train kilometers) being the average number of train kilometers covered between the occurrence of two emergencies.

Here are some of the parameters used for assessing the level of safety:

1. Comparison of increments: the total number of emergencies (N_2) and their increment ($\pm\Delta N$) according to the basic types for a certain time period compared with the previous period (N_1) in the form of:

$$N_2 = N_1 \pm \Delta N .$$

Increment rate of emergencies

$$p_{vd} = \frac{N_2}{N_1} \cdot 100\%$$

where the total number of emergencies (N_{vd}) is the sum of following emergencies:

$$N_{vd} = N_u + N_n + N_{pp} + N_{en} + N_s$$

N_u – accidents; N_n – trouble; N_s – disturbance; N_{pp} – emergency at level crossings; N_{en} – emergency caused by a natural catastrophe due to the effect of surroundings.

Coefficient of occurrence of individual emergencies according to the severity of their risk:

$$K_u = \frac{N_u}{N_{vd}} + \frac{N_n}{N_{vd}} + \frac{N_{pp}}{N_{vd}} + \frac{N_{en}}{N_{vd}} + \frac{N_s}{N_{vd}}$$

$$K_u = K_{uu} + K_{un} + K_{upp} + K_{uen} + K_{us} = 1$$

where, according to the degree of risk, the most severe coefficient of emergency occurrence is:

$$K_u = \frac{N_u}{N} .$$

Frequency of emergencies:

$$G_v = \frac{N_{vd}}{L_e} \left(\frac{\text{emergencies}}{\text{train km}} \right).$$

number of emergencies for each kilometer of exploited track length or railway network.

Degree of risk to railway traffic safety caused by accidents:

$$S_{ugv} = \frac{N_u \cdot 10^6}{\Sigma NL} \cdot \left(\frac{\text{accidents}}{10^6 \text{train km}} \right).$$

ΣNL – total number of covered train kilometers on a line or in a railway network.

Degree of risk to safety caused by locomotive defects (N_{dl}):

$$S_{dl} = \frac{N_{dl} \cdot 10^6}{\Sigma ML} \left(\frac{\text{locomotive defects}}{10^6 \text{locomotive km}} \right).$$

Degree of risk to safety caused by car defects (N_{dk}):

$$S_{uk} = \frac{N_{dk} \cdot 10^9}{\Sigma NS} \left(\frac{\text{car defects}}{10^9 \text{coach km}} \right).$$

Degree of risk to safety caused by rail breakage (N_{ls}):

$$S_{uls} = \frac{N_{ls} \cdot 10^6}{\Sigma NL} \left(\frac{\text{rail breakage}}{10^6 \text{train km}} \right).$$

Degree of risk to passenger safety:

$$S_{ubp} = \frac{10^9 \cdot N_{usp}}{\Sigma AL} \left(\frac{\text{killed passengers}}{10^9 \text{passenger km}} \right)$$

N_{usp} – total number of passengers killed in railway transport; ΣAL (pkm) – total transport expressed in passenger kilometers on a line or in a railway network.

Degree of risk to traffic safety at level crossings:

$$S_{ubpp} = \frac{N_{pp} \cdot 10^6}{\Sigma NL} \left(\frac{\text{emergencies}}{10^6 \text{train km}} \right).$$

Degree of risk to safety in relation to realized transport in passenger traffic:

$$S_{bps} = \frac{N_{vol} \cdot 10^6}{\Sigma Al} \left(\frac{\text{emergencies}}{10^6 \text{passenger km}} \right).$$

Degree of risk to safety in relation to realized transport in goods (freight) traffic:

$$S_{bts} = \frac{N_{vol} \cdot 10^6}{\Sigma Pl} \left(\frac{\text{emergencies}}{10^6 \text{ntkm}} \right).$$

Degree of risk to traffic safety in relation to total realized exploitation (in train kilometers):

$$S_{ubs} = \frac{N_{vd} \cdot 10^6}{\Sigma NL} \left(\frac{\text{emergencies}}{10^6 \text{train km}} \right).$$

Degree of risk to traffic safety in relation to train collisions:

$$S_{usv} = \frac{N_{sc} \cdot 10^6}{\Sigma AL} \left(\frac{\text{emergencies}}{10^6 \text{passnger km}} \right).$$

Degree of risk to traffic safety in relation to train derailments:

$$S_{uiv} = \frac{N_{iv} \cdot 10^6}{\Sigma NL} \left(\frac{\text{derailments}}{10^6 \text{train} \quad \text{km}} \right).$$

Degree of risk to traffic safety in relation to rail cracks:

$$S_{uls} = \frac{N_{rc} \cdot 10^6}{\Sigma NL} \left(\frac{\text{rail} \quad \text{cracks}}{10^6 \text{train} \quad \text{km}} \right).$$

Degree of risk to safety in relation to realized transport in gross kilometer tonnage:

$$S_{usbr} = \frac{N_{vd} \cdot 10^6}{\Sigma QL} \left(\frac{\text{emergencies}}{10^6 \text{gross km tonnage}} \right).$$

On the basis of the above mentioned, as well as some other, parameters of traffic safety, it is possible to assess the safety level, and to compare the realized safety levels on individual railway lines or railway networks, i.e. among the railway departments of national railways in individual countries. Table shows the level of traffic safety realized in Serbian Railways through some qualitative safety parameters in the years of 2001 and 2002.

Table

Traffic safety in Serbian Railways

Parameter	Unit	Year	
		2001	2002
G_v	Emergencies, kilometers	0,188	0,167
S_{ugv}	Accidents, 10^6 train kilometers	2,500	1,760
S_{ubp}	Killed people, 10^6 train kilometers	5,020	5,120
S_{dl}	Locomotive defects, 10^6 locomotive kilometers	202,600	233,000
S_{ubpp}	Emergencies at level crossings, 10^6 train kilometers	4,700	5,400
S_{bps}	Emergencies, 10^6 passenger kilometers	0,730	0,640
S_{bts}	Emergencies, 10^6 net kilometer tonnage	0,400	0,320
S_{usbr}	Emergencies, 10^6 gross kilometer tonnage	0,180	0,170
S_{ubs}	Emergencies, 10^6 train kilometers	32,200	32,700
S_{usv}	Train collisions, 10^6 train kilometers	0,250	0,040
S_{uiv}	Train derailments, 10^6 train kilometers	1,420	0,910
S_{uls}	Rail cracks, 10^6 train kilometers	20,100	16,600

Conclusion

Practice, facts and practical knowledge tell us that solutions leading to the increase of railway traffic safety level should be sought in decreasing the degrees of risk that originate from individual elements of the system, which may be achieved by improving the working order of technical means, establishing an adequate working organization, introducing modern technical means for regulation and safety, and, finally, by effective control and supervision over the traffic process.

In the railway traffic process, safety should be absolute. However, it is a well-known fact that there is no absolute safety in general, let alone in traffic, so we can talk only about a relative safety. This results from the fact that emergencies occur according to the law of random events occurrence; thus, there will always be emergencies in traffic under a certain set of conditions and circumstances in which they occur.

The above mentioned parameters may be useful in assessing the safety levels of individual railway departments, as well as in their mutual comparison.

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