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Trishin N. Assessment of signaling, centralization and blocking division work in the field of train traffic safety by risk-based factor analysis

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Abstract. *This article is dedicated to the main automated system which is called EK ASUI FA. It has been developed and implemented by JSCo "Russian Railways" and realizes a single information space as a means of making managerial decisions in order to positively impact on emerging risks in signaling, centralization and blocking division. This system allows to analyze several parameters which characterize the state of production processes, related to ensuring the safety of train traffic: maintenance, the organization of the production process, technical equipment, logistics, personnel. Special attention has been paid to the current methodology and up-date or develop a new method for assessing risk in signaling, centralization and blocking division work. It's important because the results of factor analysis and assessment of the risk factors influence on the state of control technical objects are the basis of a risk-oriented approach in the audit activities of JSCo "Russian Railways" in the field of train traffic safety.*

Keywords: *railway, risk, factor analysis, risk factor, risk management, EK ASUI FA*

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1. Introduction.

The term "risk" occupies a central place in the issues of analyzing and assessing train traffic safety. This term is used in countless regulatory framework based on the latest scientific achievements in the field of ensuring the train traffic safety and forecasting cases of its violation. In addition, several automated systems developed and implemented by JSCo "Russian Railways" realize a single information space as a means of making managerial decisions in order to positively impact on emerging risks in signaling, centralization and blocking division:

– automated system for analyzing the reliability of railway signaling, centralization and blocking devices (hereinafter – AS ANSh) [1, 2];

– automated system for statistical analysis of reliability indicators and prescriptive management of processes in the field of automatics and remote-control systems (hereinafter – AS ANPSh);

– a unified corporate platform for resource, risks and reliability management at the life cycle stages of railway automatics and remote-control objects (hereinafter – EKP URRAN-Sh) [3-6];

– a unified corporate automated infrastructure management system of JSCo “Russian Railways” in terms of the formation of factor analysis of risks in the field of train traffic safety (hereinafter – EK ASUI FA) [7, 8].

The first three mentioned systems are based on the Resource, Risk and Reliability Management and Analysis methodology called by the Russian acronym URRAN. The last automated system is of the greatest interest because at the moment it is actively used as the main tool in the indication of risks and taking measures to influence their level. This is due to the fact that this system allows to analyze several parameters which characterize the state of production processes, related to ensuring the safety of train traffic. Within the framework of feasibility, the dynamics of the risk factor level is assessed once a quarter by means of the EK ASUI FA system.

2. Materials and methods

The step-by-step process of forming a risk factor analysis using the automated system EK ASUI FA is presented in the form of a flowchart in the Figure 1.

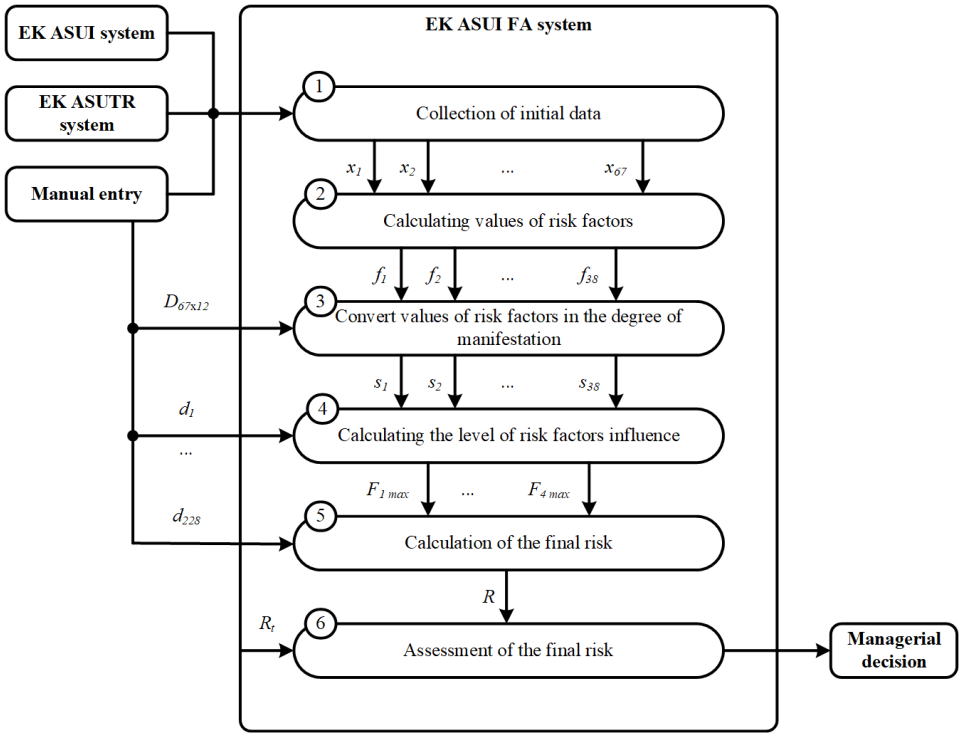


Figure 1. A step-by-step process of forming a risk factor analysis using the EK ASUI FA system.

The first step in working with the EK ASUI FA system is the collection of the source data. There is a process of transfer from the source systems 67 values (x_n) which are the initial data for calculating the values of risk factors: 24 values are synchronized from the EK ASUI system, 10 – from the EK ASUTR system, 33 values are transferred manually by the specialist who is responsible for input of initial data into a form specially designed for this purpose. On the basis of the entered data, the values of risk factors f_n the calculation is carried out in accordance with the formulas from the EK ASUI FA methodology [9]. The obtained values of risk factors are translated by 5-point system into the degree of manifestation *sn* according to the approved gradation of translation D_{67x12}.

The next step is to calculate the level of influence of 38 risk factors by multiplying the degree of manifestation by the share of influence d_m according to Formula 1.

$$F_{a,j} = s_n \cdot d_m, \quad (1)$$

where $F_{a,j}$ is the level of influence of the *j* risk factor for the case of traffic safety violation *a*;

s_n is the degree of manifestation of the *j* risk factor;

d_m is the share of influence of the *j* risk factor.

The share of influence is a single (for any signaling, centralization and blocking division and for any period of analysis) coefficient set on a 5-point system for the entire railroad network of JSCo “Russian Railways”. Its adjustment, agreed with the Traffic Safety Department, is allowed by the expert of the Situation Center for Monitoring and Emergency Management at the end of the calendar year.

Further, the level of influence of all risk factors on the occurrence of a given type of identified risk event for the control object is determined by means of the average arithmetic operation on the maximum values of the levels of influence of factors $F_{i\,max}$, selected from 4 groups of risk factors for one of the 6 analyzed cases of train traffic safety violations (*a*):

1. Collision of a rolling stock with a vehicle at a railway crossing.
2. Collision, derailment at stages and stations during train operation.
3. Collision, derailment of rolling stock during shunting work.
4. False appearance of a permissive signal indication instead of a prohibitive or more permissive one.
5. Arrow translation under the train.
6. Flooding, fire, structural damage with a traffic interruption of more than 1 hour.

$$R=\frac{\sum_{i=1}^{4} F_{i\,max}}{4}, \quad (2)$$

where $F_{i\,max}$ is the maximum value of the levels of influence of factors on the process i (i = 1 for the process “State of maintained technical objects”, i = 2 for the process “Organization of the production process”, i = 3 for the process “Logistics and equipment”, i = 4 for the process “Personnel”).

In a more extended form

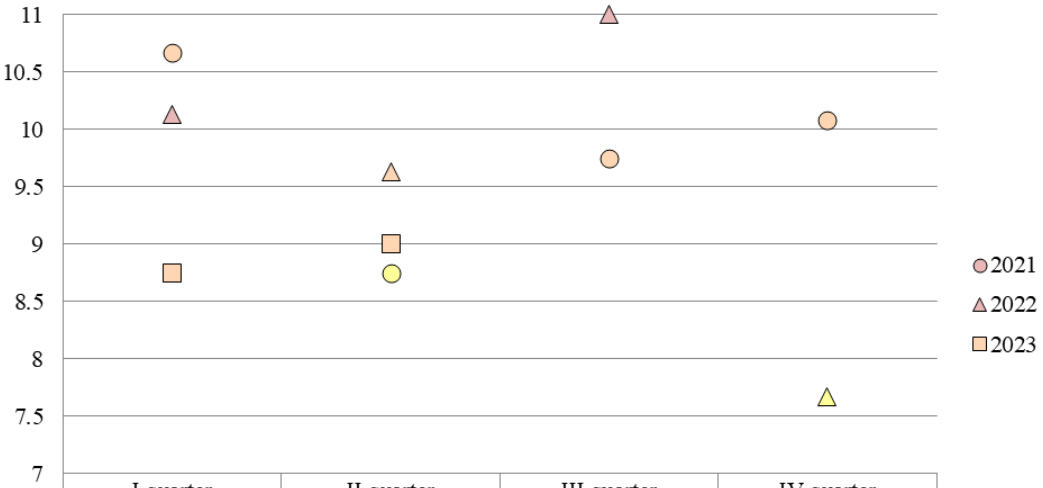
$$R=\frac{\frac{\sum_{a=1}^{6}\max_{1\le j\le 11}F_{a,j}}{6}+\frac{\sum_{a=1}^{6}\max_{12\le j\le 26}F_{a,j}}{6}+\frac{\sum_{a=1}^{6}\max_{27\le j\le 32}F_{a,j}}{6}+\frac{\sum_{a=1}^{6}\max_{33\le j\le 38}F_{a,j}}{6}}{4}$$

$$R=4\frac{\sum_{a=1}^{6}\max_{1\le j\le 11}F_{a,j}+\sum_{a=1}^{6}\max_{12\le j\le 26}F_{a,j}+\sum_{a=1}^{6}\max_{27\le j\le 32}F_{a,j}+\sum_{a=1}^{6}\max_{33\le j\le 38}F_{a,j}}{6}$$

The final step is the assessment of the final risk. The final result is checked for compliance with the target range set for the calendar year for a particular level of the final risk (unacceptable, undesirable, acceptable, not taken into account). Based on the ranking results, the level of the final risk is assessed, conclusions are drawn on the effectiveness of previously developed measures, and management decisions are made to reduce the risk of train safety incidents or maintain it at the same level.

3. Results and Discussion

Final risk levels of Murmansk signaling, centralization and blocking division from the 4th quarter of 2021 to the 2nd quarter of 2023 is presented in the Figure 2.



	I quarter	II quarter	III quarter	IV quarter
2021	10.67	8.75	9.75	10.08
2022	10.13	9.63	11.00	7.67
2023	8.75	9.00		

Figure 2. A step-by-step process of forming a risk factor analysis using the EK ASUI FA system.

3.1 Mathematical base

From a mathematical point of view, the risk R is the product of the probability of an incident p and its consequences c which will manifest themselves if this hazardous event occurs:

$$R = p \cdot c, \quad (3)$$

where p is the probability of an incident occuring;

c is the consequences of the occurrence of the incident.

Based on the study of the principle of functioning of the EK ASUI FA system, it can be said that at the moment the calculation of all 38 risk factors does not reflect either the probability of occurrence of one of the six investigated cases of violation of train traffic safety, or the damage to which these events can lead. Accordingly, at the moment it is not correct to call the calculated values risk factors of signaling, centralization and blocking division work in the EK ASUI FA system.

Attention should also be paid to the current scoring of risk factors which does not reflect the real state of affairs. For example, the minimum possible value for the risk factor “Non-compliance with maintenance technology” is 5.00 (“dangerous”). As a result, all participating divisions a priori do not have any opportunity to reduce it even in the absence of cases of technological violations for the period under consideration in accordance with the calculation formulas of the EK ASUI FA methodology [9].

In addition, according to the results of a manual verification calculation based on the formulas of the EK ASUI FA methodology [9] and the initial data of the Murmansk signaling, centralization and blocking division, uploaded to the EK ASUI FA system, for the 4th quarter of 2021, a discrepancy was found in the calculation of three indicators (“Track circuits”, “Switch”, “Traffic lights”) and, as a consequence, their further incorrect translation into the degree of manifestation. It should be noted that within the framework of a single calculation, this error affected all signaling, centralization and blocking divisions of Russian Railways and, as of today, has already been eliminated.

In determining the final level of risk of a hazardous event occurring at a signaling, centralization and blocking division, the impact of each of the risk factors is not taken into account. In particular, from the 4th quarter of 2021 to the 2nd quarter of 2023, none of the 38 risk factors, that would be classified as “very dangerous” or “extremely dangerous” in terms of impact significance were identified in the Murmansk signaling, centralization and blocking division. In addition, the final risk level based on the results of the work of the division is calculated without taking into account the individual features of its location and working conditions. As a result, the individual conditions in which the division is located, and the

distinctive features of its work in each quarter, are not currently taken into account. At a minimum, the quarters are at different times of the year, so there are different levels of influencing factors. For example, the risk of increased hardware failures during thunderstorm seasons is higher compared to other types of failures. The situation is similar for the risk of failures of track circuits operating in winter conditions. From the point of view of correctness, the final risk level should be calculated as the sum of the values of all possible risks at the linear enterprise. The current state of affairs suggests that all sub-processes are declared a priori the same, in terms of risks, which requires justification or research.

An important problem is the evaluation of the final risk: failure to meet the target ranges of risk levels is equated with the actual level, which is not a correct action. The ranking of the final risk was performed without reference to the values of risk factors. In particular, the area of unacceptable risk level for a calendar year is determined by selecting 20% of control objects with the highest value of the final risk based on the results of the fourth quarter of the previous year. Figure 3 shows how the ranking zones of the final risk level changed during three years (from 2021 to 2023). There is a dynamics of decrease in the boundaries of the final risk level. A striking example is the zone of undesirable risk in 2021, which is already a zone of unacceptable risk in 2023.

<table>
<tr><th>The name of the final risk level R</th><th>2021</th><th>2022</th><th>2023</th></tr>
<tr><td>Unacceptable (very high)</td><td>$R \geq 10.71$</td><td rowspan="2">$R \geq 9.75$</td><td rowspan="3">$R \geq 9.25$</td></tr>
<tr><td>Undesirable (high)</td><td>$9.36 \leq R < 10.71$</td></tr>
<tr><td>Acceptable (medium)</td><td rowspan="2">$7.25 \leq R < 9.36$</td><td rowspan="2">$8.6 \leq R < 9.75$</td></tr>
<tr><td>Disregarded (low)</td><td rowspan="2">$8.2 \leq R < 9.25$</td></tr>
<tr><td></td><td></td><td rowspan="2">$6.83 \leq R < 8.6$</td><td rowspan="2">$5.01 \leq R < 8.2$</td></tr>
<tr><td></td><td rowspan="2">$R < 7.25$</td><td></td></tr>
<tr><td></td><td></td><td>$R < 6.83$</td><td>$R < 5.01$</td></tr>
</table>

Figure 3. Categorization of risk levels from 2021 to 2023.

Also, the target indicators applied in the EK ASUI FA system are not correlated with the target indicators of technical objects failures when forming a factor analysis. In such a case, the failure rate of automatic blocking and electrical interlocking systems, laid down in the design and recalculated by means of the system maintenance life, obsolescence, operating conditions and other factors, is not taken into account. It is possible to achieve the goal of avoiding failures, but not less than the permissible number of failures of the system laid down at its design. At present, auto-blocking and electrical interlocking systems are not referred to zero-failure systems.

As a result, the EK ASUI FA system uses an averaging approach in assessing of train safety incidents. There is also evidenced by the following specific things.

The risk factor “Number of driver comments on the state of traffic lights” takes into account both the driver comments on the visibility of traffic lights and the condition of name plates, but the risk of traffic safety violations from contamination of the name plates and from violation of the traffic light visibility requirements belong to different categories of significance.

Failures of shunting traffic lights when calculating the risk factor “Traffic lights, light indicators” are not taken into account as their number is not included in the calculation, but the risk of occurrence in the EK ASUI FA system “Collisions, derailment of rolling stock during shunting operations” is estimated.

All of the above mentioned facts speak about the quality of automatic formation of risk factor analysis in signaling, centralization and blocking division work, make us think about the reliability and mathematical literacy of the calculations.

3.2 The regulatory and methodological base

For the purpose of a unified approach to working with the EK ASUI FA system, no regulatory and administrative document has been developed that defines the way of report generation or the column with the applied value, which acts as the initial value for the calculation of the risk factor. As a consequence, it leads to a lack of uniformity in the filling in the initial data from source systems and the impossibility to control the correctness of entering the initial values during automated or manual entry.

From the point of view of transparency and openness of the calculation, the possibility of adjusting the gradations of translation a risk factor to the degree of its manifestation according to a 5-point system is not regulated and, as a result, there is no notification of this event at all levels of management of Russian Railways. It should also be noted here that the algorithm of actions is not described when translating to the degree of manifestation of the value of the indicator in the case when its value is a boundary value in the range of translation.

It is unknown whether in such a situation the degree of manifestation is taken to a lower or higher side.

There is no possibility for the expert to regulate the applied shares of influence in an open and transparent way. It is worth noting that in some cases in the calculation the share of influence plays a decisive role in the multiplication compared to the degree of manifestation. There is no opportunity to familiarise oneself with the objectivity of the application of the share coefficients. As of today, there is no possibility to view the initial data, as well as the degrees of manifestation, shares of influence and the final value of risk for the specialists of the division because the EK ASUI FA system is not available to be installed at the workplace of a linear enterprise specialist.

It should be added that the factor analysis, carried out in the EK ASUI FA system, is not used for signaling, centralization and blocking division that specialize in repairing of railway automatics and remote-control objects (only for specializing in the maintenance of them).

3.3 Conclusion

The results of factor analysis and assessment of the risk factors influence on the state of control technical objects are the basis of a risk-oriented approach in the audit activities of JSCo “Russian Railways” in the field of train traffic safety.

Summarizing what was said earlier, it should be noted that at the moment special attention should be paid to resolving controversial issues in order to correctly form a risk factor analysis in the field of train traffic safety. It is necessary to allocate time to revise the current methodology and update or develop a new method for assessing risk in signaling, centralization and blocking division work.

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