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Stochastic Factor Analysis of Occupational Injuries at Railway Transport Enterprises

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Abstract

Introduction. Railway enterprises are characterized by an increased labor risk, the professional activity of personnel is associated with the risk of injury. Occupational safety measures are regularly carried out in the industry. At the same time, accidents are known to occur in Russian Railways JSC (Russian Railways). Risk reduction requires a theoretical study of the problem, as well as the study of applied solutions, which determines the relevance and significance of the proposed study. The purpose of the work is to determine the resulting indicators on which the dynamics of industrial injuries in Russian Railways depends.

Materials and Methods. To identify the causes of injury to railway transport workers of the Russian Railways holding, the authors analyzed statistics for 2007–2021. We systematized and ranked 17 types of accidents, which are associated with accidents resulting in injuries. Using the Pareto chart, they were differentiated as resultant and non-resultant. We identified 7 resultants. We performed a stochastic analysis and established the relationship of each factor with the total number of accidents. The correlation coefficients were calculated.

Results. Preliminary calculations were presented in the form of a table to obtain the coefficient of stochastic dependence of industrial injuries on the number of injured employees of Russian Railways in road accidents. The value of the stochastic relations coefficient was calculated and adjusted. The average error was determined — the difference between the general injury rate and the injuries in road accidents. The results of these calculations were compared with the data of the Student's t-distribution quantile table for confidence probability. Similarly, the degree of stochastic relationships for the other resulting types of incidents was calculated and summarized in a table. The result was visualized in a diagram.

Discussion and Conclusion. The results of the conducted surveys allow us to assert that the dynamics of industrial injuries in Russian Railways JSC is determined mainly by incidents in road accidents. It is necessary to investigate their causes and develop measures aimed at improving occupational safety.

Keywords: occupational safety, road traffic injuries, stochastic analysis, railway transport.

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Introduction. Legislative acts of the Russian Federation and documented standards of Russian Railways JSC give a systematic idea of measures to protect labor, ensure the safety of life and health of employees [1,2]

Russian Railways JSC owns the railway infrastructure of the Russian Federation and is one of the largest employers. The railway industry is a high-risk occupational hazard zone. The professional activity of railway workers is associated with the risk of injury. In this regard, the tasks of the Russian Railways JSC management are:

– occupational safety provision;

– prevention of occupational injuries;

– minimization of occupational risks.

The problem of occupational safety was studied by O. P. Petrova, S. V. Yanchiy, J. Bell, and others [1–3].

In 2007–2021, 5029 accidents with injuries and deaths were recorded at railway transport enterprises.

Injury to employees results in high economic costs for the employer. The dynamics of occupational injuries should be analyzed, and then the impact of each resulting factor should be considered pointwise.

The company is constantly working in these areas, but accidents still occur at railway enterprises, which confirm the relevance of the study of the problem [4].

The work objective is to determine the resulting indicators that affect the dynamics of occupational injuries in Russian Railways JSC.

To achieve this objective, it is necessary to identify the share of the impact of various types of accidents on the dynamics of industrial injuries of Russian Railways JSC in 2007-2021 using stochastic factor analysis.

Materials and Methods. First of all, it is necessary to rank the incidents that most affect the dynamics of occupational injuries. To do this, we use the Pareto chart. It allows us to determine 20% of the most significant indicators that provide 80% of changes in the dynamics of occupational injuries[3].

Based on the statistical data of industrial injuries of Russian Railways JSC in 2007-2021, we will form a Pareto chart (Fig. 1). On the left axis of the ordinates we note the total number of injury cases, on the right — an interval scale of 0–100 %. On the abscissa axis we note the indicators of accidents. Let us construct a cumulative curve. To do this, we will plot the points of accumulated amounts on the graph field, which on the right axis of the ordinates will be equal to the quantitative value of the accumulated cumulative percentage for each type of incident. Let us connect them.

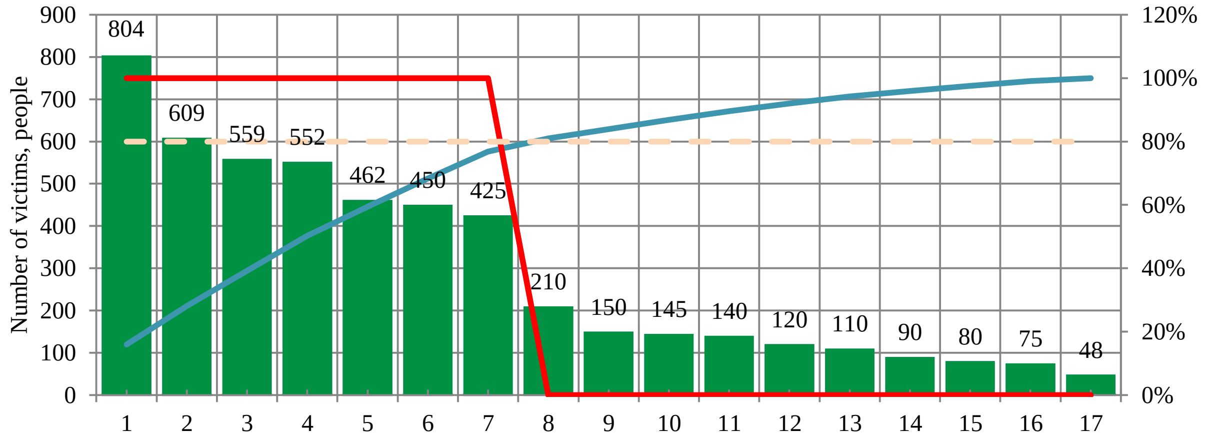

Fig. 1. Pareto chart — distribution of accidents by types of incidents: 1 — traffic accidents; 2 — falling on the surface; 3 — falling from a height; 4 — electric shock; 5 — impact of cargo movement; 6 — impact, crushing; 7 — hitting, impact, clamping by rolling stock; 8 — fall, collapse of materials, cargo, structures; 9 — exposure to harmful chemicals; 10 — impact, clamping, unrelated to rolling stock; 11 — prick, cut; 12 — impact of objects flying off from the impact; 13 — contact of a foreign body with eyes; 14 — accident, crash on railway transport; 15 — falling at sudden braking of rolling stock; 16 — illegal actions of other persons; 17 — exposure to extreme temperatures

[1] The Labor Code of the Russian Federation. Article 210. The main directions of state policy in the field of labor protection. State Duma, Federation Council, Available from: http://www.consultant.ru/document/cons_doc_LAW_34683/ed198846c41aa4fc2123f3abe0fe692a5587c5ed/ (accessed 12.08.2022). (In Russ.).

[2] Organization standard. STO RZD 15.001-2020 "Occupational safety management system in Russian Railways JSC. General provisions". Russian Railways JSC. Moscow: Russian Railways JSC, 2020. p. 46 (In Russ.).

[3] Organization standard. STO RZD 1.05.515.2-2009 "Methods and tools for improvements. Pareto Analysis". Russian Railways JSC. Moscow: Russian Railways JSC, 2009. p. 18. (In Russ.).

To divide the factors into resultant and non-resultant, we construct a horizontal line from the axis of the cumulative line to the intersection with the Pareto curve. From the place of this intersection, we draw a segment to the abscissa axis. The factors to the left of the segment are resultant, and to the right — non-resultant.

The diagram shows that in 2007–2021 the resultant types of accidents in Russian Railways were:

– traffic accidents (804 people);

– falling on the surface (609 people);

– falling from a height (559 people);

– electric shock (552 people);

– impact of transported goods (462 people);

– impact, pressure (450 people);

– accidents, hit, clamping by rolling stock (425 people).

Let us determine the accidents that most affect the statistical indicators of industrial injuries in Russian Railways. To do this, we will perform a stochastic analysis of the totality of the resultants. Let us establish the presence (absence) and significance of the corresponding correlation relationships [5, 6]. The correlation coefficient determines the interdependence of changes in the values of factors (from –1 to +1).

Let us find out the degree of interrelation of each *i*-th factor in different types of accidents from the total number of accidents. Let us calculate the correlation coefficients [7–9].

Let us establish how the dynamics of industrial injuries in Russian Railways depends on road accidents (the largest number of victims, Fig. 1).

Let us calculate the correlation coefficient r_{xy} , which determines the stochastic relationship between the variables x (the number of injured workers in *i*-th types of accidents) and *y* (the total number of injured workers in accidents at work):

$$r_{xy} = \frac{\sum(x_i - \bar{x}) \text{ x } (y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \text{ x } \sum(y_i - \bar{y})^2}}, \quad (1)$$

where x_i — the values taken by the variable$x$; y_i — the values taken by the variable y.

Results. Let us present the preliminary calculations in the form of a table to obtain the coefficient of stochastic dependence of industrial injuries on the number of injured employees of Russian Railways in road accidents in 2007–2021.

Table 1

Calculated data for obtaining the stochastic relations coefficient

Year	x	y	$x_i - \bar{x}$	$y_i - \bar{y}$	$(x_i - \bar{x})^2$	$(y_i - \bar{y})^2$	$(x_i - \bar{x}) \times (y_i - \bar{y})$
2007	63	573	22.40	237.43	501.76	56373.31	5318.45
2008	52	650	11.40	314.70	129.96	99038.20	3587.62
2009	52	650	11.40	314.70	129.96	99038.20	3587.62
2010	67	583	26.40	247.31	696.96	61163.25	6529.04
2011	41	410	0.40	74.70	0.16	5580.59	29.88
2012	59	369	18.40	33.45	338.56	1119.13	615.54
2013	37	336	–3.60	1.07	12.96	1.14	–3.84
2014	44	275	3.40	–60.30	11.56	3635.68	–205.01
2015	33	220	–7.60	–115.30	57.76	13293.32	876.25
2016	40	223	-0.60	–112.30	0.36	12610.54	67.38
2017	23	182	–17.60	–153.30	309.76	23499.86	2698.02
2018	34	168	–6.60	–167.30	43.56	27988.17	1104.16
2019	23	152	–17.60	–183.30	309.76	33597.66	3226.02
2020	20	119	–20.60	–216.30	424.36	46784.24	4455.71
2021	21	120	–19.60	–215.30	384.16	46352.64	4219.81

Correlation coefficient between the variables under consideration is $r_{xy} = 0.86$. To determine its significance, we will make an adjustment modulo:

$$|\bar{r}| = \sqrt{1 - (1 - r^2)\frac{n-1}{n-2}}; \tag{2}$$

where $|\bar{r}|$ — the adjusted value of the stochastic relations coefficient; r — the calculated value of the stochastic relations coefficient calculated by formula (1).

According to the results of calculations we get $|\bar{r}|$ = 0,89.

Next, we will perform the calculation with the obtained correlation coefficient r_{xy} . Let us determine its average error m_r (the difference between general injuries and injuries in road accidents)

$$m_r = \sqrt{\frac{1-r^2}{n-2}}. \tag{3}$$

Substituting the calculated values into formula (3), we get $m_r = 0.14$.

To assess the significance of r_{xy} we determine the statistical value of $t_{\text{ст}}$ by formula:

$$t_{\text{ст}} = \frac{|\bar{r}|}{m_r}. \tag{4}$$

Substituting the calculated values into formula (4), we get $t_{\text{ст}} = 6.21$.

The results of the study are comparable with the data of the Student's t-distribution quantile table for a confidence probability $1 - a = 0.99$, depending on the number of degrees of freedom $v = n - 2, \alpha_1 = 0.05$ and $\alpha_2 = 0.01$.

For $t_{\text{ст}} \leq t_{\alpha=0,05}$ the null hypothesis is determined, where $r = 0$. This indicates that the connection is not essential. When $t_{\text{ст}} > t_{\alpha=0,01}$ the null hypothesis is not accepted and the connection between the phenomena is considered established [7–9].

In this case 6.21 > − 6.29, that is $t_{\text{ст}} > t_{\alpha=0,01}$. The null hypothesis is rejected, and the connection between the phenomena is considered established.

Similarly, we calculate the degree of stochastic relationships for the other resulting types of incidents and summarize them in Table 2.

Table 2

Calculation results of stochastic relationships of the resultant types of incidents

No.	Incident	r_{xy}	$\lvert\bar{r}\rvert$	m_r	$t_{\text{ст}}$
1	Road transport	0.86	0.89	0.14	6.21
2	Falling on the surface of one level	0.62	0.64	0.22	2.92
3	Falling from a height	0.65	0.68	0.20	3.25
4	Electrical accident	0.39	0.41	0.26	1.59
5	Impact of transported goods	0.53	0.55	0.23	2.36
6	Impact, pressure	0.43	0.45	0.24	1.81
7	Impact, clamping by rolling stock	0.51	0.52	0.24	2.19

Figure 2 provides the calculated values of the significance of stochastic relations (coefficients and their statistical values).

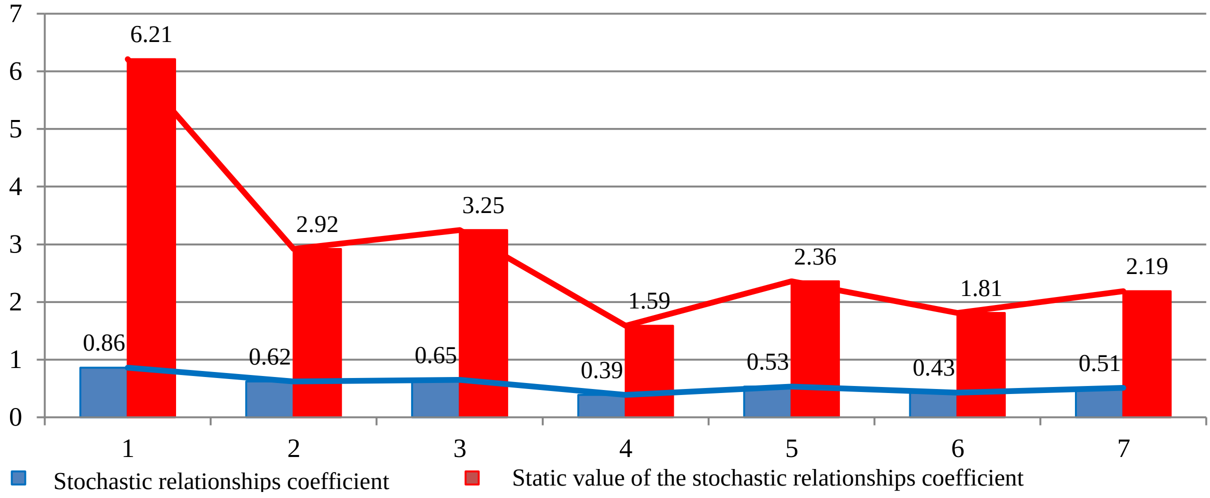

Fig. 2. Significance of stochastic relations: 1 — traffic accidents; 2 — falling on the surface of one level; 3 — falling from a height; 4 — electrical accident; 5 — impact of transported goods; 6 — impact, pressure; 7 — impact, clamping by rolling stock

The calculations have shown that all the studied resultant types of accidents are stochastically interrelated with the dynamics of industrial injuries of Russian Railways JSC in 2007-2021. The factor of injury in road accidents has the greatest weight.

Discussion and Conclusion. All things considered, the dynamics of industrial injuries in Russian Railways JSC is determined mainly by road traffic incidents. It is necessary to investigate their causes, which will make it possible to develop preventive measures aimed at improving occupational safety in the industry.

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Conflict of interest statement

The authors do not have any conflict of interest.

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