Proceedings of the 13th International Conference "Reliability and Statistics in Transportation and Communication" (RelStat'13), 16–19 October 2013, Riga, Latvia, p. 13–19. ISBN 978-9984-818-58-0
Transport and Telecommunication Institute, Lomonosova 1, LV-1019, Riga, Latvia

EXPERT ASSESSMENT OF CLIMATE FACTORS INFLUENCE ON THE RAILROAD SAFETY

Boris Misnevs[1], A. Melikyan[2]

Transport and Telecommunication Institute
Lomonosova str. 1, Riga LV-1019, Latvia
[1]Phone: (+317)67100675. Fax (+317) 67100660. E-mail: bfm@tsi.lv
[2]Phone: (+317) 26063620. E-mail: melik@aircom.lv

The expert assessment of meteorological risk influence on the safe operation of the railroad transport is examined in the article. Basing on the expert questionnaire data, the summary range matrix has been worked out. The collected data serves as the basis for the meteorological risk level assessment on the railroad.

The coefficient of the climate danger has been calculated grounded on the data analysis of 17 Latvian railroad stations, which are approximately similar in terms of traffic intensity and in number of refusals. This allowed conducting station ranging according to the level of climate risk.

Keywords: statistical data, risk, expert estimation

1. Introduction

Railroad is a complicated technical system with the natural connection of its hubs to the country geography. Railroad is working on a continuous basis during day and night all year round. It connects a country into the unified whole. Uncontrolled weather conditions influence considerably on the railroad track network.

The important instrument of raising the level of railroad safety, reliability and continuity of functioning is the monitoring of the present condition and maintenance of railroad track infrastructure objects. At present the methods of railroad risk experience summary are being actively developed. They include information collection activities (data collection about accidents, descriptions, facts connected with the accident), analysis, registration (classification and storage) and processing information connected with these facts. Latvia's entry into the EU put forward absolutely new demands on providing high mobility, intermodality, comfort, passenger rights observation, cargo transportation as well as new requirements concerning transport and environment interaction.

Meteorological factors that influence on the railroad safety is quite a complicated problem that requires registration of all climate factors. Weather anomalies happen rarely and have got a considerable amount of uncertainty and in some cases lead to emergency situations on the railroad.

Qualitative and quantitative integral estimation of risk forming factors acquires great importance. This is very important for the EU railroads where a lot of cases of safety violations happen because of the climate factors influence.

Latvian Railroad has (LR) been chosen as an object of the research. But the gathered results have universal character and can be used by the other railroad companies.

Basic railway safety tasks connected with the dangerous meteorological phenomenon are researched and classified based on the example of Latvian railroad infrastructure.

Questions of monitoring methods representation and railroad experience risk summary in the Railway Agency Database of Interoperability and Safety database are studied.

Risk management depends on the factors that influence its size. In the future, for the estimation of the meteorological risk level we suggest to research risk-forming processes connected with identification, risk analysis and making decisions that include maximizing positive and minimizing negative consequences, appearance of risk situations which influence railroad work.

Methodology that was elaborated by us represents the approach for the estimation of the level of meteorological risk and it includes the following stages:

1. Selection the set of indexes that characterise the conditions of the EU railroad functioning.
2. Estimation the influence level of every specific weather phenomenon on the safe railroad operation with the help of expert assessment method.
3. Definition of meteorological risk level on the railroad.

European Union (EU) is a political and economic unity of 27 European countries where every state maintains its railroad track in different technical conditions that depend on infrastructure and the track specification.

2. Selection of the Set of Indexes that Characterise the Conditions of the EU Railroad Functioning

Statistical data about the annual indexes of railroad services was used as initial information. The source was European Railway Agency Database of Interoperability and Safety (ERADIS) – archive [1]. Information about the amount and conditions of passenger and cargo transportation by railroad, the violations that happened and the financial expenses necessary for violation elimination is given in ERADIS reports. In particular they contain detailed (classified according to countries and types) data about the violations that occurred on the railroad. This data was selected and underwent cluster analysis.

During the analysis the most part of the variables presented in the database was filtered. The most complete (some countries do not give full information about their railroad work) interesting and informative indexes were selected.

To eliminate the influence of the difference in indexes meaning on the cluster results all indexes underwent extra normalization. The average meaning of the corresponding indexes in all EU countries and indexes relative meanings for every country were calculated. The countries fell into groups in quite expected way, see Table 1[2].

Table 1. Country grouping into clusters

No. Cluster	Country
1	Latvia, Lithuania, Estonia, Hungary, Bulgaria, Slovakia, Belgium
2	Finland, Portugal
3	France, Germany, Great Britain, the Netherlands(12 countries in total)
4	Poland, Romania, Slovenia, Greece

3. Elaboration of Criteria for Meteorological Level Risk Estimation on the Railroad

When choosing the way of estimation of the meteorological risk (this is done for the safe functioning of the structural elements of the railroad) it is necessary that all the suggested activities were based on the elements of scientific approach which means factor systemizing and analysis.

It is suggested to define the degree of meteorological phenomenon risk for the railroad objects. With the help of this estimation it is possible to estimate quantitatively the meteorological risks and work out the method of countermeasures.

The basis of the indexes under investigation that characterise the environmental conditions which influence on railroad safety was the data collected on Latvian Railroad during 2006-2013. In the beginning 24 factors were suggested as influential and dangerous phenomena.

Factors offered for analysis as well as the members of expert committee were discussed with respect to their validation. The expert committee included Latvian Railroad and the subsidiary enterprise LLC “LDZ CARGO” staff members. An expert could include an extra factor into the list of suggested dangerous meteorological factors that in his or her opinion was significant for railroad risk characterising. In the course of the discussion 10 factors were selected.

- R_1- air temperature above 25ºC;
- R_2- air temperature below 25ºC ;
- R_3-; rain;
- R_4- snowfall;
- R_5-downpour;
- R_6- 3 hour long down pour;
- R_7-snow;
- R_8-sleet or ice crusted ground;
- R_9- blizzard, snowstorm;
- R_{10}- wind

The number of experts was defined according to the following criterion: the number of factors included in the questionnaire must be thirds smaller than experts.

The most important factors according to the experts' opinion were classified as first-rank so they had the least sum of ranks (*Ri*) but the indexes with the weakest influence had the most sums of ranks (*Rn*). These criteria were rated according their importance.

Because of the fact that the index that characterizes the level of meteorological risk on the railroad is a complex of criterion

$$R = f(R_1, R_2, R_3, \ldots, R_n) \quad . \tag{1}$$

So these criteria were ranged according to their importance aiming to find out the cases of accidents in the natural risk sphere on Latvian railroad.

$$R_1 < R_2 < R_3 \ldots \ldots R_n \tag{2}$$

The number of experts was defined [3], according to the following criterion: the number of factors included in the questionnaire must be thirds smaller than experts.

$$N_e = 3n = 30 \quad , \tag{3}$$

where n is the number of indexes included in the questionnaire.

Thirty experts-specialists were questioned and basing on the questionnaire data a summary questionnaire or range matrix was made, see Table 2.

The criterion of the correct table filling is the equality of the sums in all columns:

$$\sum_{j=1}^{n} R_{ij} = \frac{(1+n)n}{2} = 55 \quad , \tag{4}$$

Where R_{ij} – range j – its index y^{i} – expert

Kendall concordation index is used to define the coherence of expert estimations [2].

The meaning of the concordation index can be located in the range from 0 and up to 1. If W=0 so it means that experts' opinions are not coherent. If W=1 so the experts' estimations are fully coherent.

$$W = \frac{12S}{m^2\ (n^3 - m)} \tag{5}$$

n – number of objects of the ranging feature (number of experts)
m – number of ordinal variables under analysis
S – the sum of ranges squares is calculated by formula

$$S = \sum_{j=1}^{n} R_{ij} - \left[\frac{\sum_{j=1}^{n} \sum_{i=1}^{m} R_{ij}}{n}\right]^2 \tag{6}$$

$\mathbf{R_{ij}}$ – the ranges placed by the group of experts

The value of concordation index is defined by Pearson criteria χ^2 with the number of freedom degree $(\mathbf{n}-\mathbf{1})$ using the formula

$$\chi^2 = m(n-1)W = \frac{S}{\frac{1}{12} mn(n+1)} \tag{7}$$

If the calculated value of χ^2 is bigger than it is the table the hypothesis of accidental coincidence of experts' opinion is rejected.

In the course of the expert estimations processing the value of concordation index was estimated $W = 0.489$. Its meaningfulness was calculated according to Pearson criteria $\chi^2 = 159{,}953$.

When the number of freedom degree is $\kappa \geq 30$ and in our case $\kappa = 30$ the critical value for table meaning definition χ^2 can be calculated by the approximate formula.

$$U_1 = \kappa\left[1 - \frac{2}{2\kappa} + t(\rho)\sqrt{\frac{2}{9k}}\right]^3, \tag{8}$$

where $\kappa = n - 1$ $t(\rho)$ is the critical value for the normal allocation of 5% level of amount, [3]
After the substitution $U_1 = 45.71701$

If we compare the calculated value of Pearson criteria - $\chi^2 = 159{,}953$ with the table value $\chi^2 = 45.71701$ for 5% level of amount, we can say with the probability P = 0,95 that the experts' opinion of the indexes amount estimation of meteorological risk on Latvian Railroad is not accidental or random. χ^2 calculated table, $159{,}953 > 45.71701$

Table Error! Reference source not found.. Ranging the criteria of meteorological risk according to their amount

N Expert	N Criteria R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}
1	2	1	3	3	2	4	6	10	9	8
2	2	2	2	5	3	2	3	8	7	6
3	1	2	4	6	5	2	4	5	8	7
4	4	2	6	5	6	2	3	8	5	3
5	5	1	4	3	7	5	2	8	4	4
6	3	2	3	5	5	2	4	5	2	4
7	2	4	3	5	4	2	6	5	4	6
8	2	1	2	4	3	2	6	6	5	6
9	3	2	3	6	3	2	5	9	8	6
10	3	3	5	5	5	4	4	10	9	6
11	1	1	3	4	5	2	4	8	7	6
12	2	1	2	5	3	2	5	7	9	6
13	3	2	2	5	4	2	5	6	6	8
14	4	2	5	5	3	2	3	6	5	5
15	1	2	6	5	4	3	5	5	6	8
16	5	3	2	4	2	1	3	6	5	6
17	3	2	5	10	8	6	4	6	5	5
18	2	1	2	8	3	2	7	9	8	7
19	4	3	6	5	3	2	3	9	9	7
20	5	3	4	8	5	2	4	6	6	7
21	2	3	2	4	2	1	3	6	6	6
22	7	4	3	8	5	2	6	6	5	9
23	1	2	3	10	5	3	5	9	9	8
24	5	4	3	8	3	2	4	8	7	7
25	3	3	3	9	6	4	6	9	5	5
26	4	2	2	7	5	4	6	8	6	4
27	2	1	6	7	4	2	3	9	6	6
28	3	2	2	6	3	2	6	7	7	6
29	4	2	3	5	3	2	6	4	5	5
30	2	2	3	5	4	2	3	10	8	7
Total:	90	65	102	175	123	75	134	218	191	184

The sum of the entitled ranges can serve for defining the degree of meteorological risk amount.
The diagrams demonstrate the condition of meteorological risk level on the railroad from the expert point of view, see Figure 1.

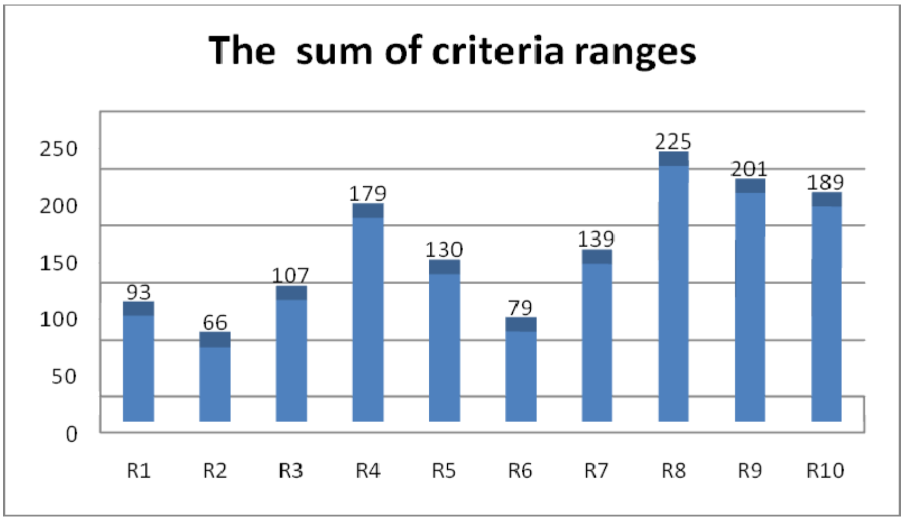

Figure 1. Placement of ranges criteria level of dangerous meteorological factors according to expert estimation

It is necessary to point out that there are abrupt drops of the level of amount of the entitled ranges Figure 1, so basing on that we can divide them according to the estimated level of risk on the railroad, see Figure 2.

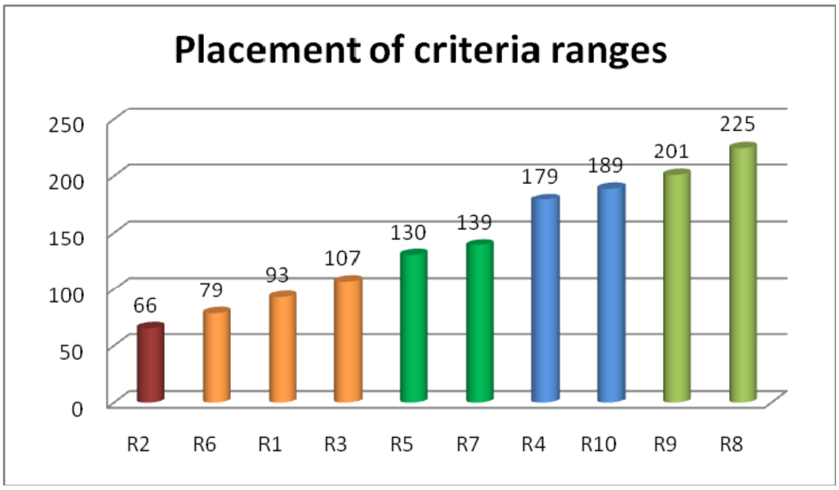

Figure 2. Placement of criteria ranges of the level of dangerous meteorological factors

R_2 is in the first group. R_1,R_3,R_6 are in the second group, which shows their belonging to the same regularity because their importance increases on exponent. R_5,R_7 are in group three, R_4,$R_{10}$are in group four. There are considerable drops in meteorological risk estimation in group five where R_8,R_9 are placed. Such criterion is viewed as less significant and can be excluded from the list because of being less significant.

Ranging the meteorological factors helped to exclude dangerous and non-significant phenomena and define the main ones.

4. Defining the Level of Meteorological Risk

Nature-climate risk is viewed as a pure risk (with no definite event) and this does not allow us to use it in financial risk management [3]. We cannot control the nature processes we can only grade their negative influence.

Seventeen Latvian railroad stations that are approximately similar in terms of the intensity of traffic and the number of refusal were chosen for the analysis. The data was processed and underwent cluster analysis. The comparison of cluster analysis results were made according to two methods: Ward's method and method K-average (K-means).

Table 3. Latvian railroad station cluster results

N. Cluster	Station
1 – maximum complexity of technical conditions	Rēzekne II, Rīga pass, Salaspils
2 – complicated technical conditions	Jāņavārti, Krustpils, Ogre, Šķirotava “A” parks, Šķirotava “B” parks, Torņakalns, Zemitāni
3 – normal technical conditions	Daugavpīls pass, Olaine, Pļaviņas, Tukums I, Ventspils I, Zasulauks
4 – minimal complexity of technical conditions	Jelgava I

Index of climate risk was calculated

$$C_{clim.risk} = \sum_{i=1}^{n} DE_{ij}, \tag{9}$$

where DE_{ij} – index that characterizes meaning of i – climate risk index on the j permanent way division territory that is calculated by the formula:

$$DE = \frac{F_{ij}^{DE}}{F_i^{DE}} \tag{10}$$

where F_{ij}^{DE} is coefficient, which characterises the frequency of some definite risk phenomenon on the territory of j permanent way division during the last thirty years.

Table 1. Ranging stations according to the level of climate risk

Group	Range of value $C_{clim.risk}$	Value $C_{clim.risk}$	Station
1 – maximum climate risk	more than 7	8,09	Rēzekne II
		7, 71	Ventspils I
		7,24	Daugavpīls pass
		7,14	Rīga pass
2 – dangerous climate conditions	from 5 to 7	6,32	Ogre
		5,98	Pļaviņas
		5,21	Tukums I
3 – normal level of danger	from 3 to 5	4,79	Šķirotava “A” parks
		4,63	Torņakalns
		4,52	Krustpils
		3,65	Šķirotava “B” parks
4 – minimal climate risk	from 1 to 3	1,2	Jelgava I
		0,89	Zemitāni

One of the formal requirements to the risk estimation is its additiveness, if one event risk equals R_1but another risk event equals $R_2$and both events happen simultaneously than the total risk level equals the sum of particular value [3].

$$R_{aggregate} = R_1 + R_2 \tag{11}$$

5. Conclusions

The results of expert estimation confirmed the validity of the assumptions made by the authors about the existence of the significant dependence between the environmental- climatic factors and the safety level on the railroad. These results will be used for the checking of the previously obtained estimation models and for railroad safety level forecasting. The coefficient of the climate danger was calculated grounded on the data analysis of 17 Latvian railroad stations, which were approximately similar in terms of traffic intensity and in number of refusals. This allowed conducting station raging according to the level of climate risk.

The use of the results obtained during the research and the further analysis of socio-economical indexes in the grouped countries can help to develop the safety rise measures on European Union railroads.

References

1. *Accident Investigation notification and reports*. Retrieved June 3, 2013, from - http://pdb.era.europa.eu/safety_docs/naib/default.aspx
2. Melikyan, A., Misnev, B. (2010). Forecasting Models of Accident Risks on the Railway. In Proceedings of the First International Conference on Road and Rail Transport (CETRA 2010) (pp.881-889). Opatija, Croatia.
3. Hopkin, Paul. (2012). *Fundamentals of Risk Management* (p.440), 2nd Edition. Kogan.
4. Agresti, Alan. (2002). *Categorical Data Analysis* (p.710). John Wiley & Sons.