Management and economic efficiency criteria in the organization of safe rail transportation

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Abstract. Ensuring safety in rail transportation is achieved by creating a certain management structure of the company, which contributes to the improvement of economic sustainability and organization of safe traffic. The analysis of indicators to assess the state of traffic safety in JSC "Uzbekistan Temir Yullari" (the object of the study) allowed the authors to formulate the purpose of the study, which is to develop algorithms for carrying out measures to ensure traffic safety on the basis of economic criteria of management efficiency. Following stages of planning as the analysis of indicators of safety and identification of problems, analysis of causes of the identified problems, development of ideas objectives, setting measurable goals, checking the achievement of objectives, developing options for action achieve the goals. For each stage on the basis of methods of correlation, regression and factor analysis algorithms of their carrying out are developed. The concept of measures is developed to improve the economic efficiency of traffic safety management, depending on the method of management. With the functional approach, the main direction of the plan is to strengthen control, and with the process approach-the regulation of technological processes and training of production personnel. The authors believe that the implementation of the proposed recommendations for decision - making on traffic safety is a comprehensive preventive measure to ensure a guaranteed level of safety, which will improve the overall economic efficiency of traffic safety management in the railway company.

1 Introduction

In the railway transport the traffic safety (TS) is provided by the necessary works planning, depending on the current state of the infrastructure facilities and rolling stock. Such a kind of approach may turn out to be insufficiently effective at a shortage of investment placement or limited volume of the operating costs, which does not ensure the company economic stability, which can be achieved with the transportation processes effective management [1,2]. In order to achieve this, it is necessary to clearly identify the event planning stages, develop their implementation algorithms and propose a concept for the traffic safety provision formation plan.

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The purpose of this study is to develop the measures implementation algorithms to ensure the organization economic sustainability (by the example of the national railway company JSC "Uzbekistan Temir Yullari" (UTY) based on the traffic safety parameters). This achievement of this goal involves the following tasks solving:

- to analyze the indicators and assess the TS state in JSC UTY;
- to highlight the measures implementation stages to ensure TS;
- to develop these measures implementation algorithms taking into account the economic sustainability indicators and propose their implementation concept.

Having analyzed the company economic stability indicators, the authors identified the following measures planning stages:

- analysis of TS indicators and problems identification (stage I);
- analysis of the causes of the problems identified (stage II);
- the goal idea formation (stage III);
- setting the measurable goal (stage IV);
- the goal achievement verification (stage V);
- the measures options development to achieve the goals set (stage VI).

2 Materials, methods and objects of study

The materials for the study were the reporting data of the State Joint-Stock Railway Company "Uzbekistan Temir Yullari" for 2004-2016 according to the state of traffic safety on the network, Comprehensive Program for Development and Modernization of the Company for 2015-2019, Concept for the Strategic Development of the Company until 2021, as well as the works analysis of the foreign and domestic researchers in the field of organization economic sustainability and TS provision in the railway industry.

The study is based on the methods of correlation, regression and factor analysis, statistics of time series, probability theory and mathematical statistics [3]. The object of the study is the Joint Stock Company “Uzbekistan Temir Yullari”.

3 Study results

According to the measures planning stages identified by the authors that ensure the company economic stability, taking into account the TS parameters, it is developed their implementation algorithms.

Stage I problems possible options may be the following:

1. Traffic accidents with serious consequences (loss of life, damage to the extent that the rolling stock is excluded from inventory, damage from a traffic accident over a specified limit).
2. An increase in the number of traffic accidents and events with grave consequences (loss of life, damage to the extent that the rolling stock is excluded from inventory, damage from a traffic accident over a specified limit).
3. Negative dynamics of the accident rate.
4. Low efficiency and effectiveness of TS support processes.

At this stage, the sufficiency evaluation of the provided statistical data amount of the TS to be analyzed is carried out. If necessary, an additional information collection on TS is performed and, based on the analysis, a conclusion is made about the achieved security level, “bottlenecks” and proposals to overcome the identified problems are formulated [4-6].

The second stage “Analysis of the causes of the problem” is carried out in the following sequence, presented in Fig. 2

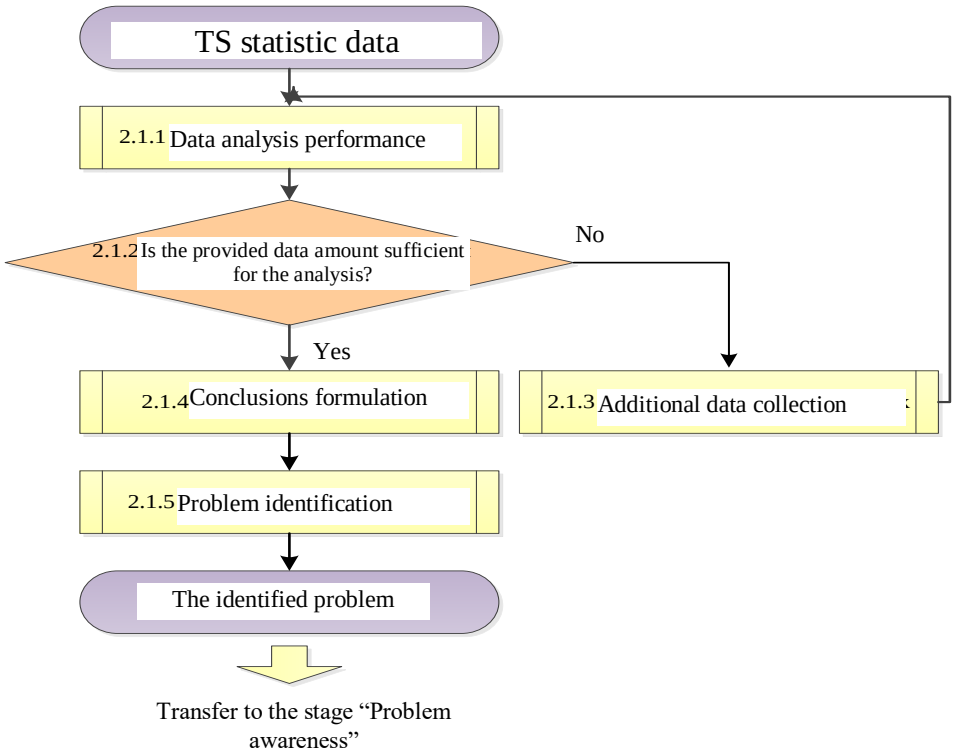

Fig. 1. Stage I Algorithm "Analysis of TS indicators and problems identification"

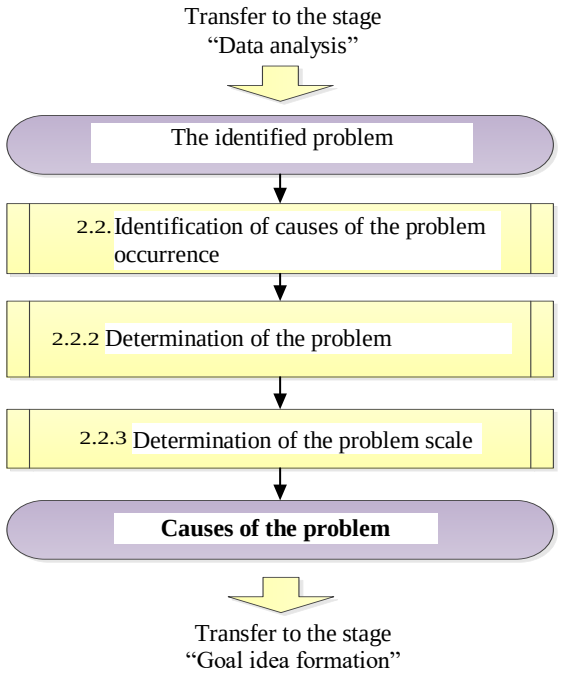

Fig. 2. Algorithm of stage of the problem causes analysis

The scale of the problem is determined by the management level in whose area of competence the problem solution resides in and the problem specialization is associated with the specific processes of TS provision [7]. So, if there is a problem of poor quality of repair, then it can be attributed to both the production processes and the management process and the resource support processes [8, 9].

Problem occurrence causes identification is carried out by constructing a cause and effect diagram or Ishikawa diagram. The example is presented in Fig. 3.

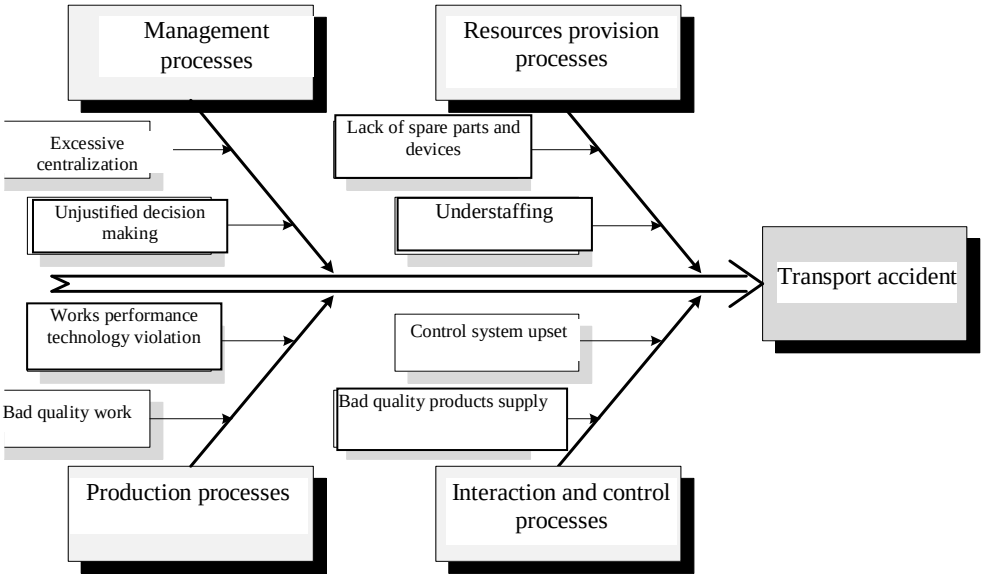

Fig. 3. The cause and effect diagram of a traffic accident occurrence

The Ishikawa diagram makes it possible to determine the problems causes in the processes of TS provision for formation in the future of the goal ideas for the identified problems solving [10].

The "Goal ideas formation" stage algorithm is presented in Fig. 4.

The problem causes ranking in order of importance is carried out by using the Pareto chart (Fig. 5). This example illustrates the main causes of the trains coming-off due to the production processes breakdowns of the track section maintenance.

It can be seen from the Pareto chart that the most significant reasons for the rolling stock coming off occurrence in the trains due to the fault of the track establishment are violations of the production technology of repair and track works performance in the presence of simultaneous deviation from the norms of track maintenance and turnouts.

To reduce the number of coming off, it is necessary to work on the most significant causes. Several works on methods are possible, such as:

1) technological processes regulation;
2) advanced training of the production personnel;
3) strengthening of control over the technological operations progress.

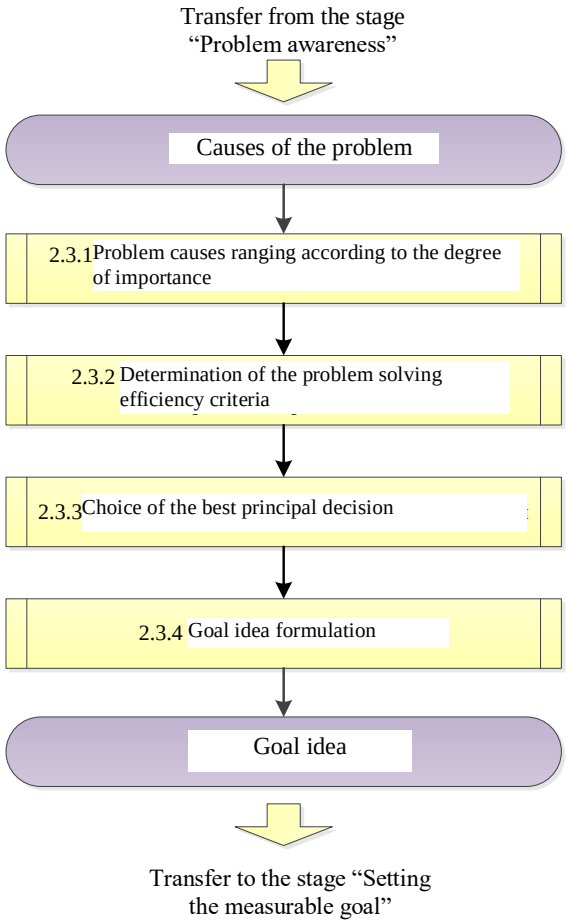

Fig. 4. The goal idea formation algorithm

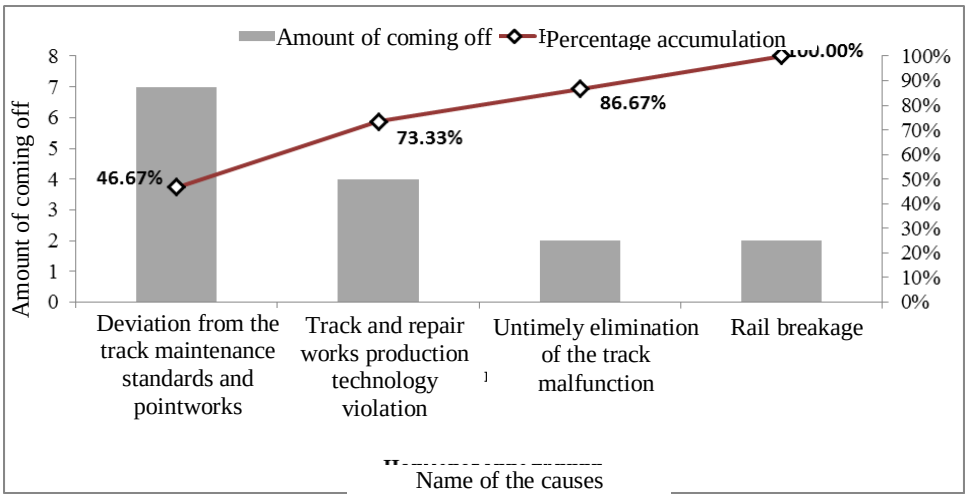

Fig. 5. Pareto chart of the rolling stock coming off amount in trains due to the fault of the track establishment

For an objective comparison of the abovementioned methods, their effectiveness criteria are established, such as:

- performance;
- implementation period;
- implementation costs.

Table 1 compares these options according to the presented criteria based on the expert assessments method, which is quite illustrative from the point of view of the criteria significance and options for influencing the causes within each criterion. Employees of the Central Office, of the regional level and linear enterprises in the amount of 20 people were involved as the experts, who, on the basis of a work questionnaire assigned the criteria and impact options on the causes according to their importance order.

Table 1. Determining the values of performance criteria for the impact options on the identified causes (expert estimates)

Criterion Name	Impact options on the causes		
	Technological processes regulation	Further training of production personnel	Strengthening the control over the technological operations progress
Performance (0.3)	0.25	0.3	0.45
Implementation period (0.3)	0.3	0.2	0.5
Implementation costs (0.4)	0.4	0.35	0.25
TOTAL	0.95	0.85	1.2

In accordance with Table. 1 the most effective option for the identified causes elimination is to strengthen the control over the technological operations progress. However, such an approach in the long term perspective is quite expensive compared to the other options, therefore, it is efficient to count on the technological processes regulation and ensuring the personnel competencies on the unconditional regulations implementation [11-14].

The goal idea formulation shall contain the main directions in which it is planned to work to increase the TS level, as well as the ways to achieve it.

Therefore for the example under consideration, the goal idea involves reducing the number of rolling stock coming off in trains by strengthening the control over the current track maintenance as a short-term measure and as a result of the technological processes regulation and the necessary personnel competencies establishment in the long term. The Stage IV Algorithm is shown in Fig. 6.

The main indicators of the TS state in the railroad sections of JSC UTY are:

- absolute indicators (number of accidents, events, failures);
- relative (number of accidents / million train-km);
- economic (financial losses from accidents occurred, events, failures);
- train delay time;
- number of trains delayed.

A comprehensive indicator of the traffic safety state assessment is the TS state integrated assessment, which characterizes not only the current TS state, but also allows to identify its level changes dynamics over a certain period of time [14].

To check the goal idea achievability, according to the authors, it is necessary to draw up a factor model of the following form:

$$R = a_1 \cdot x_1 + a_2 \cdot x_2 + \ldots + a_n \cdot x_n = \sum_{i=1}^{n} a_i \cdot x_i , \quad (1)$$

where R – is the security level;

a_i – is factor weight;

x_i – is the numerical value of the factor.

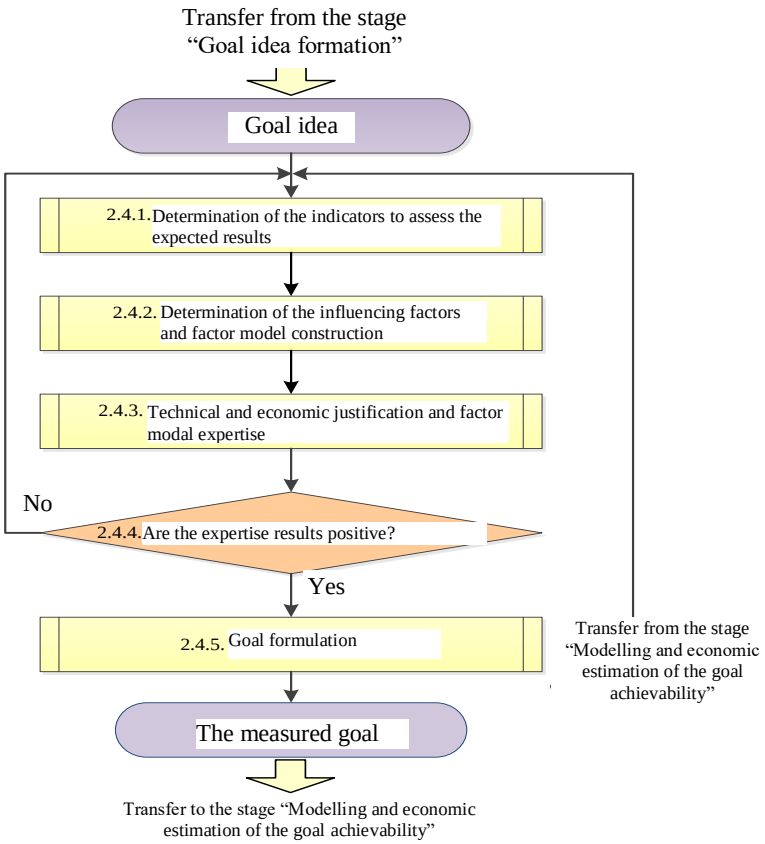

Fig. 6. Algorithm of Stage "Setting the measurable goal"

As an example we considered two main factors:

x_1 - the number of deviations from the maintenance standards, $x_1 = 200$;

x_2 - the number of the works technology violations, $x_2 = 192$;

R – the number of the rolling stock coming off in trains, $R = 15$.

Based on the observations of the indicators R, x_1, x_2 over the several periods, the following factor weights were established:

$$a_1 = 0{,}045;$$
$$a_2 = 0{,}031.$$

The factor model takes the following form:

$$15 = 0{,}045 \cdot 200 + 0{,}031 \cdot 192$$

In accordance with this model, the coming off amount reduction from 15 to 12 (by 20%) through the fault of the track establishment is achieved due to the influence on the first factor x_1:

$$12 = 0{,}045 \cdot 133 + 0{,}031 \cdot 192,$$

by decreasing its value from 200 to 133 (by 67%).

If a positive expert assessment of the goal set is established, a measurable goal is formulated. Otherwise, other possible improvement options are being reviewed in terms of the TS level increase. Therefore, for the considered example, a measurable goal is to reduce by 20% the rolling stock coming off number in trains by reducing the deviations number from the track devices maintenance standards by 33%.

Stage V "The goal achievement verification" includes the following sub-steps:

- goal achievement model development in accordance with the PDCA cycle (planning - action - verification - adjustment);
- economic evaluation of the goal achievement measures;
- performance indicators determination of the goal achievement stages;
- adjustment, if necessary, of a measurable goal;
- the goal achievement activities list formation.

The final stage "The measures options development to achieve the goals set" passes 3 sub-steps:

1. Development of the Plan Concept.
2. Formation of the main directions for the TS improvement.
3. Compilation of a list of measures for the TS.

4 Discussion

The authors believe that it is advisable to perform the plan development on an alternative basis. Table 2 presents two possible plans of measures to reduce the technology violation number of production of repair and track works and current maintenance for the example under consideration.

The plans detalization showed that the plan to strengthen the control will require considerable expenses associated with the constant funds payment for the staff motivation and the costly mechanism to perform additional control functions [15].

In the long term, the most effective way to reduce the number of the production technology violations of repair and track works and the current maintenance will be the technological processes regulation and advanced training of the production personnel [16].

Table 2. Development example of the Concept, the main directions and measures to reduce the number of the production technology violations of repair and railway works and current maintenance for the two plan options

Plan No 1 (strengthening of control)	Plan No 2 (technological processes regulation and advanced training of the production personnel)
Concept development example for the two plan options	
• control quality improvement (control regulation, preparation of the control results records forms, automation of collection and analysis of the control results data); • determination of competencies and advanced training of controllers; • control levels number increase	• regulatory documents preparation that determine the implementation order, the resources amount and technological process control; • management mechanisms organization for the continuous improvement of technological processes on the basis of regulations and internal audits; • personnel training in the process-oriented system for the technological processes implementation.
Development example of the main directions of the plan two options	
Management and resource provision	
• quality control analysis; • control regulation rationale; • analysis of the personnel qualifications performing control functions; • resource provision analysis of the technological processes; • preparation of the concept and program of control strengthening in the track establishment.	• analysis of the measures taken in recent years to improve the technological processes performance quality; • rationale of the need to introduce the process approach in the technological processes implementation; • process approach introduction concept preparation.
Production	
• briefing; • mentoring; • -the strengthening of personnel motivation	• preparation of production process regulations; • personnel training in the process approach foundations;

for quality work.	• creation of a coordination council, working group and internal audit group
Control and corrective measures	
• introduction of additional control functions for various officials; • automated systems implementation for collecting and analyzing the technological processes performance data.	• regulations implementation records organization; • conducting audits; • development of the plan of measures to eliminate inconsistencies in the technological processes.
Measures development example for two options of the plan	
Management and resource provision	
• preparation, coordination and approval of technical specifications for the analytical documents development; • development of analytical materials; • examination, coordination and approval of the developed documents; • decision-making on the technological processes implementation quality increase program.	• preparation, coordination and approval of technical specifications for the analytical documents development; ; • development of analytical materials; • examination, coordination and approval of the developed documents; • decision-making on the process approach implementation program to the technological works organization.
Production	
• organization and implementation of the mentoring motivation; • introduction of additional motivation for the high quality of the work performed; • updating the TS issues in regulatory documents on technological processes.	• agreement conclusion with a consulting organization for the production process regulations development; • preparation, approval of the program and the personnel training in the basics of the process approach; • preparation of the order by the head of the enterprise on creation of the coordination council, working group and internal audit group.
Control and corrective measures	
• development of measures to eliminate formalism in the personal TS standards implementation reports; • carrying out activities to introduce additional control of technological processes, which implementation is directly related to the TS provision; • the best practices advancing in the implementation of an automated system for collecting and analyzing data on the technological processes quality.	• approval of standard records forms of the technological operations performance results in accordance with the developed regulations; • approval of the audit schedule; • development of the plan of measures to eliminate inconsistencies in the technological processes.

Depending on the management method used in the railway administration, it can be used one or another plan. If a hard management style (functional approach) dominates, then plan No. 1 is preferable. If the process approach prevails, then there are all the prerequisites for using plan No. 2. The difference between the specified plans is the time to obtain the desired result. Upon execution of the plan No. 1, the result can be obtained within the shortest period of time, but it will be accompanied by constant costs for the control mechanisms implementation over the technological operations performance. And it should be noted that in many cases the control strengthening possibilities are almost completely exhausted.

Upon execution of the plan No. 2, the result will be obtained after the time required to regulate the main production processes and the personnel advanced training, herewith the costs of the measures will be one-time.

Therefore, in the long term perspective, in order to reduce the rolling stock coming off amount in trains, it is more efficient to focus ultimately on plan No. 2 as the most effective one according to the financial costs criteria and sustainable result.

5 Conclusion

Introduction into practice of the proposed recommendations for the TS ensuring decision making should be considered as a comprehensive preventive measure to provide a guaranteed security level. This methodology can be considered as the TS management mechanism at various sections, routes or corridors, which use will make it possible to regulate the revisions, strengthen the internal control and increase the overall economic efficiency of the TS provision system.

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References

1. L. Kazanskaya, E. Palkina, *16th International Scientific Conference Proceedings*. ZU - University of Zilina. 839-846. (2016).
2. X. Liu, M. Rapik Saat, C.P.L. Barkan, Journal of Hazardous Materials, **260**, 13 (2013) https://doi.org/10.1016/j.jhazmat.2013.04.052
3. B. Roets, M. Verschelde, J. Christiaens, European Journal of Operational Research, **271(1)**, 224-237 (2018) https://doi.org/10.1016/j.ejor.2018.04.045
4. K. Adjetey-Bahun, B. Birregah, E. Châtelet, J.-L. Planchet, Reliability Engineering & System Safety, **153**, 1-14 (2016) https://doi.org/10.1016/j.ress.2016.03.015
5. W. Huang, B. Shuai, B. Zuo, Y. Xu, E. Antwi, Journal of Loss Prevention in the Process Industries, **61**, 94-103 (2019) https://doi.org/10.1016/j.jlp.2019.05.021
6. F. Ghofrani, Q. He, R. M. P. Goverde, X. Liu, Transportation Research Part C: Emerging Technologies, **90**, 226-246 (2018) https://doi.org/10.1016/j.trc.2018.03.010
7. O. Abuobidalla, M. Chen, S. Chauhan, Journal of Rail Transport Planning & Management, **10**, 46-61 (2019) https://doi.org/10.1016/j.jrtpm.2019.06.001
8. Z. Lukasik, W. Nowakowski, T. Ciszewski, J. Freimane, *Procedia Computer Science*, **149**, 159-166 (2019) https://doi.org/10.1016/j.procs.2019.01.119
9. J. Heil, K. Hoffmann, U. Buscher, European Journal of Operational Research, In press, corrected proof, Available online 12 June 2019 https://doi.org/10.1016/j.ejor.2019.06.016
10. E.G.C. Crawford, R.L. Kif Safety Science, **110 (B)**, pp.195-205, (2018) https://doi.org/10.1016/j.ssci.2018.07.004
11. J. Liu, F. Schmid, W. Zheng, J. Zhu, Reliability Engineering & System Safety, **189**, pp.218-231 (2019) https://doi.org/10.1016/j.ress.2019.04.030
12. K. Li, Sh. Wang, Safety Science, **109**, pp.398-402, (2018) https://doi.org/10.1016/j.ssci.2018.06.008
13. J. Yin, T. Tang, L. Yang, J. Xun, Transportation Research Part C: Emerging Technologies, **85**,548-572, (2017) https://doi.org/10.1016/j.trc.2017.09.009
14. F.E. Santarremigia, G.D. Molero, S. Poveda-Reyes, J. Aguilar-Herrando, Safety Science, **110 (B)**, 206-216 (2018) https://doi.org/10.1016/j.ssci.2018.03.001
15. Y. Gao, L. Yang, S. Li, Applied Mathematical Modelling, **40 (7–8)**, 4921-4934 (2016) https://doi.org/10.1016/j.apm.2015.12.016Get rights and content
16. P.M. Salmon, G.J.M. Read, G.H. Walker et al., Safety Science, **110 (B)**, Pages 31-46 (2018) https://doi.org/10.1016/j.ssci.2018.02.014