International Journal of Engineering Applied Sciences and Technology, 2019
Vol. 4, Issue 4, ISSN No. 2455-2143, Pages 29-35
Published Online August 2019 in IJEAST (http://www.ijeast.com)

RISK MANAGEMENT IN RAILWAY DURING OPERATION AND MAINTENANCE PERIOD: A LITERATURE REVIEW

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Abstract – **The railroad transportation system facilitates the movement of people and goods and plays an important role for social and economic welfare, but behind that there are many train accidents which cause material and non-material losses. Risk management is expected to reduce the accidents that arise by identifying risks and several methods for handling them. Based on the nature of the risks that arise in train construction can be seen from two sides, namely the technical and non-technical sides. Therefore this journal aims to identify risks based on technical and non-technical characteristics of the risk. On the technical side, the most frequent risks arise in the form of derailment and collision, while non-technical risks are in the form of human error and wind obstructions when the train is traveling (crosswind). Risk management of transportation infrastructure is a complex task that usually involves various stakeholders from the individual, government and private sectors so that multi-sector collaboration is seen as an important element of risk management.**

Keywords – **Technical risks, non-technical risks, trains, freight trains, high-speed trains.**

I. INTRODUCTION

Risk, in the railroad sector, can be defined as relating to accidents and events that lead to injury to passengers and employees [3]. For the national risk assessment model, the definition of a generic railway system, technical specifications and operating systems is very important and must be considered [10]. Recent structured hazard identification work in the industry has confirmed a high risk scenario of types of accidents such as collisions, derailments and fires [3]. Accidents and incident statistics include not only workers, but also a large number of people who do not work in the industry, including children and community members [3]. The recent derailment of trains in Washington State in the US serves as a timely reminder to take stock of risks associated with new technologies so that preparations can be made to minimize their impact [5].

Providing efficient and reliable services is a general-purpose train system. Increased capacity utilization can improve system efficiency during normal operation. Therefore, there is a potential risk of increasing capacity utilization rates, and must be examined carefully in the service-design process [11].

Therefore, it is very important to develop new risk analysis methods to identify major hazards and assess the risks associated in ways that can be accepted in various environments where such good tools cannot be applied effectively or efficiently [3]. Railway risk analysis is to increase the level of safety to protect their assets, customers and employees while increasing safety and reducing maintenance costs for railroad assets and environmental impacts [4].

II. METHODOLOGY

Writing this article is based on a review of the literature obtained online from trusted sources which discusses the identification of risk and risk management in railways which are then reviewed and synthesized to provide the latest information

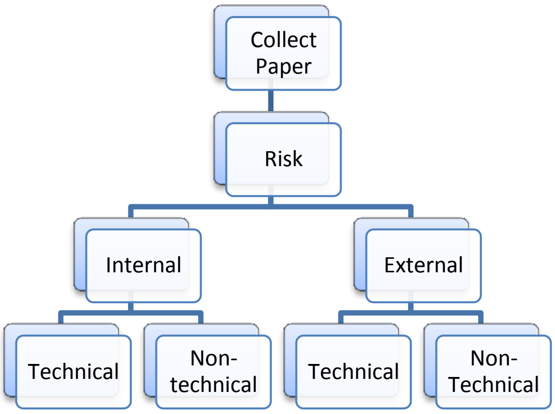

Figure 1. Study Framework

III. RESULT AND DISCUSSION

The review of scientific article publications was carried out from several sources, namely: Google Scholar, ScienceDirect, ASCE, ResearchGate, Springer, ProQuest, EBSCO, etc. The list of selected articles analyzed from the aspect of risk identification in railway are as shown in Table 1.

Table 1. Summary of the paper reviewed

No	Paper Identity	Risk Identification				Result
		Internal		External		
		Technical	Non-Technical	Technical	Non-Technical	
1	[1] Liu et al. (2011).	√	X	X	X	The proposed model can be expanded by including additional risk factors to more accurately assess the effectiveness of various derailment prevention efforts to reduce transportation risks.
2	[2] He et al. (2016).	√	X	X	X	The proposed method can effectively reduce risk, ensure structural safety, and maintain sustainable development.
3	[3] An et al. (2011).	√	X	√	√	The proposed risk assessment system can evaluate qualitative and quantitative risk data and information related to the railway system effectively and efficiently.
4	[4] An et al. (2016).	√	X	√	√	The risks associated with the railroad system can be assessed effectively and efficiently, and more reliable and accurate results can be obtained.
5	[5] Crawford and Kift, (2018).	X	X	√	√	Six trends are presented to increase awareness of the health and safety impacts of operators on trains, namely: cognitive challenges for operators, increasingly complex adoption of end-user systems, increasing steady job equity especially in the control room, developing data security and privacy issues, expanding demand for data analysis and paradigm changes that arise in safety practices.

Table 1. Summary of the paper reviewed (continued)

No	Paper Identity	Risk Identification				Result
		Internal		External		
		Technical	Non-Technical	Technical	Non-Technical	
6	[6] Giappino et al. (2016).	X	X	√	√	Vehicle aerodynamic optimization in terms of cross-wind behaviour requires different actions for high-speed and low-speed trains.
7	[7] Kaeeni et al. (2017).	√	X	X	X	The derailment accident risk assessment classification model can be used for safety systems in railway networks by presenting high-quality information to predict accidents
8	[8] Liu et al. (2018).	√	X	X	√	The general risk analysis developed in this journal can estimate the specific risks of the causes of hazmat transportation accidents (hazardous material).
9	[9] Wang et al. (2017).	√	X	X	√	Identifying three main aspects of the railway system safety risk concept: (1) system risk not the absence of system safety, (2) system risk is dynamic and predictable, and (3) system risk presents a dynamic evolutionary process in accidents.
10	[10] Leitner. (2017).	√	√	X	√	The model developed will provide a generic model of safety risk in Slovak railways that will increase industry knowledge about the risks of operation and maintenance.
11	[11] Lai and Chen. (2017).	X	√	X	X	Service risks in capacity utilization can be obtained and compared using the proposed concepts and processes.
12	[12] He et al. (2015).	X	X	√	√	High public acceptance of high-speed trains, due to low perceptions of environmental and social risks and high economic and social benefits.
13	[13] Otto et al. (2019).	X	X	X	√	the importance of multi-sectoral partnerships is seen as an important element of risk management in the Sendai Framework for Disaster Risk Reduction from rail operators
14	[14] An et al. (2013).	√	√	X	√	The proposed intelligent rail safety risk assessment system can provide comprehensive results of safety risk analysis in two formats, namely risk scores in the specified area and risk categories along with a percentage of possibilities.
15	[15] Berrado et al. (2011).	√	√	X	√	The involvement of all stakeholders is a prerequisite for the successful identification of hazards in the railroad level crossing area using functional diagrams for modelling operations.

Table 1. Summary of the paper reviewed (continued)

No	Paper Identity	Risk Identification				Result
		Internal		External		
		Technical	Non-Technical	Technical	Non-Technical	
16	[16] Putri and Amin, (2017).	√	√	X	X	5 dominant risks that cause delays in the implementation of the project construction of apartment precast panels in Summarecon Serpong based on PMBOK analysis are as follows: fewer workers installed, use of work tools that do not fit, level of tower crane, number of moulding, lack of technique.
17	[17] Randy and Amin, (2017).	√	√	X	√	Dominant risks that often occur in construction projects, consist of: internal technical factors (methods, technology, and complexity), internal non-technical (management, schedules, costs, cash flows), external predictable (inflation, environment, weather) and external unpredictable (natural disasters), this affects the level of risk.

Note: √ (discussed), X (not discussed)

Types of Risk

The three main aspects of the concept of railway system safety risk are: (1) the system of risk is not the absence of a system, safety (2) the system of risk is dynamic and predictable, and (3) the system of risks presents a dynamic evolution process in an accident [9].

However there are those that define risk as a function of system failure and the severity of loss or damage from system failure [1]. In the context of railroad transportation, the risk of train derailment is defined as the result of the frequency of railroad derailment and the average consequences of railroads [1].

Many incidents of deterioration of dangerous materials caused by train accidents, mainly due to derailment of trains. Slippage accounts for more than 72% of all types of accidents on freight trains [8]. Damaged rails or welds pose a greater risk than other causes in each class of lanes, therefore detection and prevention of damaged rails is a high priority safety activity for the U.S. railroad. High derailment risk on the track class is low, but the risk of derailment resulting from track geometry defects is relatively low on higher track classes, this may be due to the strict track geometry standards and maintenance standards. The risk of slipping on average for all track related causes is about double that of related causes of equipment [1]. In addition, especially for derailments of freight trains in Class I can be categorized into ten groups of causes, namely Broken rail or weld, Track geometry defects, Bearing failure (carriages), Broken wheels (carriages), Train handling (not including brakes), Barriers, flexed track, Wide gauge, Track-train interactions, other Axles or daily defects [8].

According to the railway accident classification in Slovakia, risks can be categorized by accident into the five main accident areas as follows: 1. Railway collisions, 2. train derailment, 3. trains, 4. crossroads, 5. trains (traffic) / safety) accident victims [10]. On the other hand, an assessment case study The risk of shunting at the Hammersmith depot has seven groups of hazards that have been identified and defined such as: (1) derailment hazard group (DHG), (2) collision hazard group (CHG), (3) train group burning (TfHG), (4) Electric shock hazard group (EHG), (5) Slipping / tripping hazard group (SHG), (6) Dropping danger group from a height (FHG), (7) Train hazard group hitting humans (TsHG) [3] while a case study of shunting risk assessment at Waterloo depot has ten groups of hazards, namely: Derailment, collisions, electric shock, slipping / tripping, falling from heights, Train trains hitting humans, Platform platform interfaces, Structural failure, Health hazards [4]

If the risk is seen from a non-technical aspect, the lack of consideration of human factors in the design of new technology has been found to cause human error. Accident analysis between 2001 and 2012 from 76 accident databases showed that 87.5 percent of all train accidents were caused by human factors, namely: human error, design errors, errors in the control room, and maintenance errors [5]. In addition to other organizational benefits such as improved safety and work performance, it is suggested that the possibility of human error can be significantly reduced when human factors are considered during the design of new technologies [5]. The acceleration of system integration and human automation design has been characterized as two important risk mechanisms for railways [5].

On the train type HSR, the source of risk and the level of death during HSR underpass operations is the failure of the Waterproofing structure, Vehicle out of control, and Over high vehicles. These risks directly affect the safety of HSR bridge operations. The effect of several core risks, such as extracting and constructing dewatering, needs to be analyzed quantitatively [2]. For projects that have passed the HSR, risk assessment is needed to determine the source of risk and the level of danger. Residual risk must be monitored during construction to ensure the safety of HSR operations [2].
One of the risks associated with high-speed rail safety is related to rolling in strong wind trajectories [6]. Crosswind behavior for high-speed trains and low-speed trains has been compared and it has been shown that, even if the HS train has a better aerodynamic shape, the corresponding aerodynamic force is higher because of the larger side area so that vehicle aerodynamic optimization in terms of crosswind behavior requires action different for high speed and low speed trains [6].

In addition, the environmental and health consequences and effects of HSR in China have emerged in public debates and policies. This encourages researchers to examine the environmental risks of high-speed railways and that shows that more residents support the construction of the HSR line than against it. Local (Chinese) government officials as well as residents along the HSR track assess that the benefits of HSR outweigh the risks (environmental and social) caused. Also, compared to nuclear and chemical risks, high-speed railroad projects are considered low-risk infrastructure projects [12].

Risk management is an approach taken to risk to understand, identify and evaluate the risk of a project and then consider what must be done about the impact and the possibility of transferring risk to another or reducing risk. Risk management consists of all sets of activities related to risk planning, assessing, handling and monitoring risks [16].
In the risk management process, the first task of risk control is risk decision making, which usually requires detailed investigation to benefit from risk mitigation measures so that an optimized plan can be obtained [2].

Several Models Developed

Fuzzy Reasoning Approach (FRA) dan Fuzzy Analytical Hierarchy Process (Fuzzy-AHP)
The advantages of the risk assessment system using FRA and Fuzzy-AHP can be summarized as: (1) can handle expert knowledge, technical assessment, and historical risk data for the assessment of railroad risk consistently, (2) can use information that is inappropriate, ambiguous and uncertain in assessment, (3) risks can be directly evaluated using linguistic expressions used in risk assessment, (4) risks can be assessed effectively based on the knowledge base built by changing information from various sources, and (5) providing more structure flexible to combine frequency of failures, consequences and consequences of consequences in risk analysis [3].

Fuzzy Analytical Hierarchy Process (Fuzzy-AHP)
The modified FAHP methodology can reduce a large number of pairwise comparisons in the decision making process significantly, it will also reduce human error in the risk decision making process so that more reliable and accurate results can be obtained. The modified method not only improves the quality of risk analysis in inappropriate situations, but also solves consistency problems when applying the FAHP method [4].

Artificial Neural Networks, Naïve Bays, Decision Tree, and Genetic Algorithm (GA)
This method has two steps, namely, first step, Artificial Neural Network, Naïve Bays, and Decision Tree are used independently to predict the risk of slipping accidents, and each method produces their prediction model as a form of probability. In the second step, the results for each model receive weights based on predictive accuracy using the genetic algorithm (GA), and make a final decision on the risk assessment of derailment accidents. This model presents high-quality information to predict accidents and GA (Genetic Algorithm) in the second step has an important role in improving performance [7].

Fuzzy Inference System (FIS) and Graphical User Interface (GUI)
The proposed intelligent system can be used to assess the risk of failure events with quantitative and qualitative information, the risk of a series of failure events and sub-systems and / or systems. Using a GUI, qualitative descriptors and basic fuzzy set concepts, Membership Functions (MF) can be easily arranged. After a qualitative

descriptor, MF and the rule base are set, the system is ready to process the safety risk analysis. This system consists of a number of page tabs to deal with setting MF parameters, developing base rules, selecting fuzzy operations, the results of the process and display of the final results [14].

IV. CONCLUSION

Dominant risks that often occur in construction projects, consist of: internal technical factors (methods, technology, and complexity), internal non-technical (management, schedules, costs, cash flows), external predictable (inflation, environment, weather) and external unpredictable (natural disasters), this affects the level of risk. One of the responses to these dominant risks is reducing risk (mitigation) and transferring risk to risks that are difficult to mitigate [17].

The risks that arise in train construction also can be seen from two sides, namely the technical and non-technical sides. On the technical side, the most frequent risks arise in the form of derailment and collision, while non-technical risks are in the form of human error and wind obstructions when the train is traveling (crosswind).

Track class enhancements generally reduce the risk of derailment related to the track, but this increases the specific cause of the risk of slipping related to equipment. These and other factors need to be properly calculated when evaluating the safety and cost benefits associated with improving infrastructure as a risk reduction strategy [1].

Risk management of transportation infrastructure is a complex task that usually involves various stakeholders from the individual, government and private sectors so that multi-sector collaboration is seen as an important element of risk management [13] and researcher in journal [15] also revealed something similar that the involvement of all stakeholders is a prerequisite for the successful identification of hazards in the railway especially in level crossing area.

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