Use of Delphi-Ahp Method to Identify and Analyze Risks in Seaport Dry Port System

Nabil Lamii[a], Fatimazahra Bentaleb[a], Mouhsene Fri[b], Charif Mabrouki[a], El Alami Semma[a]

The dry port concept has recently gained rising consideration in the multimodal transport context from the point of view both of researchers and stakeholders related to the benefits of the seaport dry port system. Given the relevance of the topic, the present paper aims to identify the potential risk factors of the three major parts that constitute the seaport dry port system and present a conceptual framework to facilitate risk factors analysis. Based on a three-step approach, starting with a systematic literature review, which resulted in 204 collected and examined papers, which allowed identifying 181 potential risk factors with an average of 60 risk factors in each major part of the studied system. In addition, we used a survey based on the Delphi technique to ensure a good extraction of data from 12 selected experts related to the seaport dry port system; then, we used the MCDM (Multiple-Criteria Decision-Making) method AHP (Analytic Hierarchy Process) in order to: 1) present a hierarchy that simplifies the complexity of the studied system in an organized structure; 2) analyze and assess risk factors based on the identified criteria. A case study involving the Moroccan seaport dry port system of Casablanca illustrates that the seaport part is critical and any major risk factor in this part can even paralyze the operations of the whole system, especially if that risk factor belongs to the human factors category or economic risk category, which is also considered in the study as a critical category.

KEY WORDS

~ Risk assessment
~ Multi-criteria approach
~ Seaport dry port system
~ AHP
~ DELPHI
~ Systematic literature review
~ Multimodal transport

a. Hassan 1st University, Faculty of Sciences and Technologies, Settat, Morocco

e-mail: n.lamii@uhp.ac.ma

b. Euromed University of Fez - URMF, Fez, Morocco

doi: 10.7225/toms.v11.n01.w12

Received on: Aug 6, 2021 / Revised on: Jan 14, 2022 / Accepted on: Feb 5, 2022 / Published online: Feb 19, 2022

1. INTRODUCTION

Risk management remains a critical pillar in any organization (Hopkins, 2011; Mabrouki et al., 2014), and the decision-makers take seriously the matter of identifying, analyzing, and controlling risk factors, due to the huge impact that may be caused.

In the last decade, the dry port concept attracted progressively more attention each year (Bentaleb et al., 2015a; Khaslavskaya and Roso, 2020; Lamii et al., 2020; Witte et al., 2019), because of the important role that it can play. In addition, the solutions that it offers for the most issues faced by seaport today, like e.g., congestion at truck access points (Tsao and Thanh, 2019), lack of space (Berg and Langen, 2015; Roso et al., 2009), increase of transport costs (Hanaoka and Regmi, 2011), and the negative environmental impact (Lättilä et al., 2013; Roso, 2007). In fact, the establishment of a dry port gives the opportunity to have a robust seaport dry port system, and it is considered as a convenient choice for many countries especially those with small access to the sea or landlocked countries.

Moreover, even with the increasing number of articles published each year treating the dry port concept (Khaslavskaya and Roso, 2020; Lamii et al., 2020; Witte et al., 2019), the risk management issue is one of the less treated topics, there are only a few articles that take this issue in consideration for all the seaport dry port system. According to Lamii et al. (2020), out of 172 articles just 8 articles treat the issue between 1980 and 202,0, and only one article that considers the whole seaport dry port system (Bentaleb et al., 2015b) presenting a multi-criteria approach for risk assessment of the whole studied system based on MCDM MACBETH method.

The risk management methods and tools differ among researchers according to the context of the studied system (Khan et al., 2015). In our case, the seaport dry port system contains three major parts (usually: seaport, railways, and dry port); each part has different risk factors. This gives a multi-criteria aspect to the studied system.

Taking in consideration the scarcity of the risk management research in the studied system and the multi-criteria aspect to the studied system, we propose in this paper a framework to identify and assess risk factors in the seaport dry port system. The framework is based on seven steps: first, identifying all the potential risk factors, then proposing a systematic structure using AHP (Analytic Hierarchy Process) to simplify and organize the studied system, in addition we used Delphi technique to insure a good extraction of data. Finally, based on AHP and the Fine Kinney method, we scored the found risk factors, which makes the analyses of these risk factors easier for the decision-makers.

The remainder of this article is organized as follows: Section 2 gives a clear definition of seaport dry port system to illustrate the concept. Section 3 explains step by step the methodology of our study and its application in choosing the case study. Finally, Section 4 presents our conclusions and discussions.

2. SEAPORT DRY PORT SYSTEM

We can introduce dry port (Figure 1) as an inland facility with or without an intermodal terminal and logistics companies, directly connected to the seaport(s) with high-capacity transport means either via rail, road or inland waterways, where customers can leave/pick up their standardized units as if directly connected to a seaport (Roso et al., 2009). This concept offers many solutions for many challenges faced by seaport; we can list the most important challenges: 1) The difficulties of managing goods due to world economy growth (Hirst et al., 2009) and maritime traffic evolution (UNCTAD, 2018); 2) Lack of space that is a result of the steady increase in the volume of merchandise trade (UNCTAD, 2018); the increase in containerization and its negative impact such as the increase of containers in distress (Berg and Langen, 2015; UNCTAD, 2018); urban growth at the entourage of seaports, which prevents seaport expansion (Hanaoka and Regmi, 2011), and separation of different types of goods for safety purposes (Santarremigia et al., 2018); 3) Congestion at seaport accesses at truck entrances because of the large number of containers accommodated and shipped at the same time. (Bentaleb et al., 2015a); 4); the increase of transport costs caused by the non-optimal management of transport flows between seaports and shippers (Lättilä et al., 2013), and 5) the negative environmental impact due to the high number of trucks used in transportation (Lättilä et al., 2013; Li et al., 2019; Roso, 2007).

However, for its advantages (Lovrić et al., 2020; Roso et al., 2019; Wide and Roso, 2021), the dry port concept attracted many researchers in the last decade (Bentaleb et al., 2015a; Khaslavskaya and Roso, 2020; Witte et al., 2019). This paper comes as result of an early research (Lamii et al., 2020) that confirmed the importance of the seaport dry port system and represents an important point in the topic of risk management issue in the seaport dry port system.

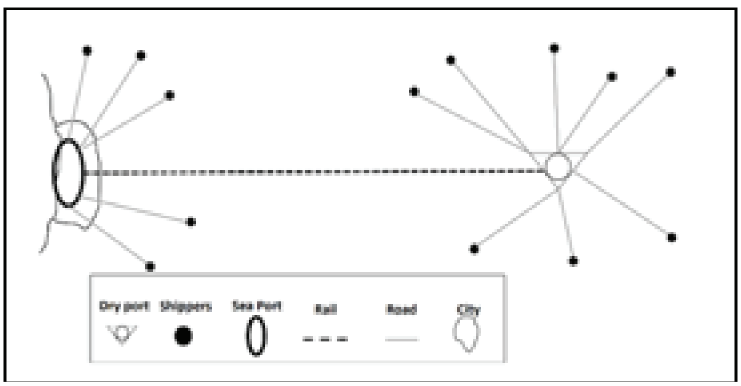

Figure 1.
Seaport dry port system (Roso et al., 2009).

3. METHODOLOGY AND APPLICATIONS

Quantitative risk assessment models are mostly used over the years to estimate uncertainties (Andrew John et al., 2014). Nevertheless, when we have a lack of data we reinforce quantitative models with qualitative methods (Jeevan et al., 2019), which allow us to take expert judgments, transfer them to quantitative data, and facilitate the analyses for decision-makers.

In this study, we proposed a framework, as shown in Figure 2, to identify and analyze risk factors of seaport dry port system. To identify risk factors, we adopt a systematic literature review treating each part of our system separately: seaport, railway, and dry port. Furthermore, we apply AHP in order to organize the seaport dry port in a systematic structure, and then we use Delphi technic to ensure a good extraction of data needed for AHP scoring. Finally, using the risk score equation inspired by the Fine Kinney method, we calculate the total risk score for each risk factor, which allows decision-makers to analyze risk factors easily.

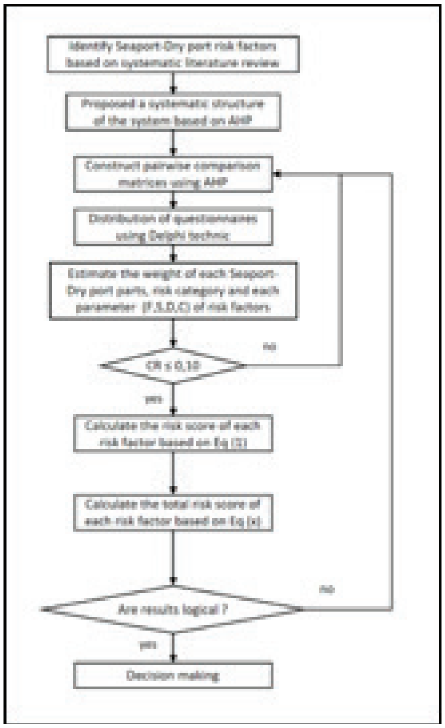

Figure 2.
Proposed framework.

3.1. Systematic Literature Review

In this phase, we focused on two main questions: first, what the risk factors that we could find in the seaport dry port system are, and second, what the categories of those risk factors are. In order to ensure valuable data that can answer these two questions, we followed a systematic literature review SLR based on seven steps (Figure 3).

Step 1. Establish the time period of our literature review:

In our SLR, we decided to limit the period of our research to the last six years 2015, 2016, 2017, 2018, 2019, and 2020. This decision was based on two reasons: 1) The goal of our SL was to identify the potential risks and the chosen interval allowed us to fulfill this goal; 2) The official start of treating risk management in the whole seaport dry port system was in 2015 according to Lamii et al. (2020).

Step 2: Define database search keywords:

The key words that we chose based on the three major parts of our system were: seaport, railway, and dry port. This led us to choose seven key words:

Maritime risk, Seaport risk, Seaport safety, Railway risk, Railway safety, Dry port risk and Dry Port safety.

Step 3: Define databases:

The choice of search engines in the realization of literature review remains a very important step. In our case, we chose five popular engines: starting with Google Scholar, one of the biggest search engines connected with almost all scientific databases; Science Direct, search engine of Scopus database; we also added IEEE, Taylor & Francis, and Springer to expand the research scope of our study.

Step 4: Collect documents

In this step, we started the collection of articles on condition that the title or the abstract of the document collected should be linked with one of our seven chosen keywords.

When we type a keyword into a search engines, each search engine displays a certain number of results found in a limited number of pages. Table 1 presents the number of articles collected in each search engine whose titles or abstracts directly related to one of our three major parts of the seaport dry port system. In our systematic literature review, we had seven keywords and five engines, which led us in the end to a total of 2,332 documents collected.

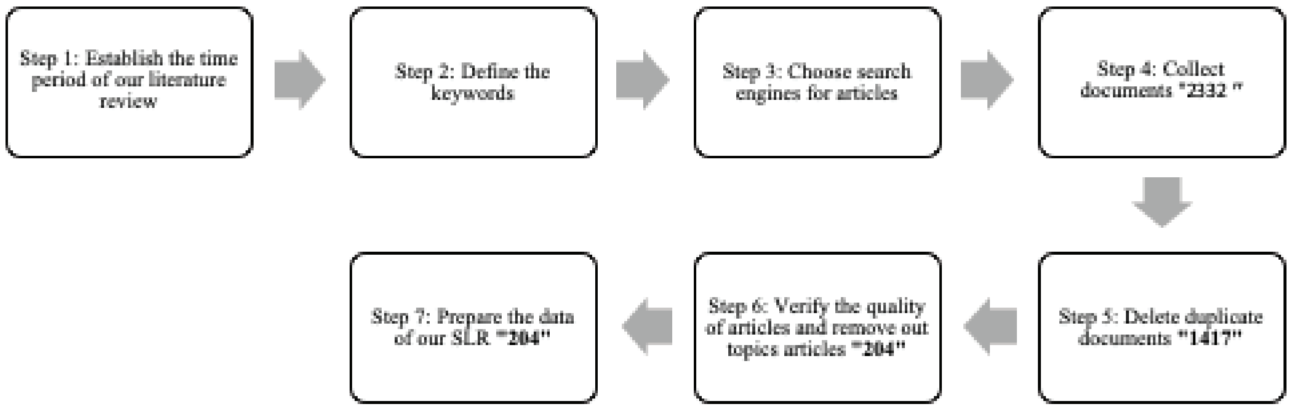

Figure 3.
Systematic literature review process.

Table 1.
Number of articles collected in each search engine.

Key word	Search engines	Articles collected
Maritime risk	Science Direct	252 articles
	Google Scholar	119 articles
	IEEE	30 articles
	Taylor & Francis	21 articles
	Springer	36 articles
Seaport risk	Science Direct	110 articles
	Google Scholar	174 articles
	IEEE	5 articles
	Taylor & Francis	14 articles
	Springer	18 articles
Seaport safety	Science Direct	84 articles
	Google Scholar	128 articles
	IEEE	13 articles
	Taylor & Francis	10 articles
	Springer	23 articles
Railway risk	Science Direct	265 articles
	Google Scholar	191 articles
	IEEE	30 articles
	Taylor & Francis	29 articles
	Springer	63 articles
Railway safety	Science Direct	277 articles
	Google Scholar	199 articles

	IEEE	86 articles
	Taylor & Francis	24 articles
	Springer	89 articles
Dry port risk	Science Direct	4 articles
	Google Scholar	12 articles
	IEEE	3 articles
	Taylor & Francis	2 articles
	Springer	3 articles
Dry port safety	Science Direct	3 articles
	Google Scholar	8 articles
	IEEE	2 articles
	Taylor & Francis	2 articles
	Springer	3 articles
TOTAL		2,332

Step 5: Delete duplicate documents '1417'

The keywords used (Risk maritime; Risk seaport; Seaport safety; Risk railway; Railway safety; Risk dry port; Dry port safety) are very close in meaning, which justifies the high number of duplicated documents that have reached 39.2% of the total number of documents collected. In this step, we deleted these duplicate articles.

Step 6: Verify the quality of articles and delete the out-topic articles '204'.

In this step, we had two conditions: first, verifying the quality of articles, and second, accurate reading of each article in order to eliminate the off-topic articles and the articles that did not belong to the seaport dry port system. Thus, we deleted all the articles that dealt with maritime risks out of seaport areas, and we limited our study to articles that belonged to the three major parts of our system: seaport, railway, and dry port. Finally, we reached a total of 204 selected articles.

Step 7: Prepare the data '204'.

This was the final step of our process. The main task here was to structure the data collected to facilitate the analysis with the aid of Nvivo qualitative data analysis software, which facilitated providing the convenient answers to our questions in order to have an idea about the potential risk factors in the seaport dry port system.

3.1.1. Article Distribution According to the Three Parts of the Seaport Dry Port System

The first result that we would like to show is the distribution of our selected articles according to the three parts of the seaport dry port system. Figure 4 shows that 66% of articles are concentrated in the railway part, 39% of articles in the seaport part, 4% of articles treat more than one part at the same time, and only 1% of the articles deal specifically with the dry port part. There are two reasons for this result. The first reason is the way in which we selected our articles. We disregarded most articles from the maritime part, and we focused only on the articles that treat the operation and activities inside the seaport. The second reason is the limited number of articles that deal with the research of risk management in the dry port. These two reasons explain the high percentage of articles that treat risk management in the railways (Figure 4).

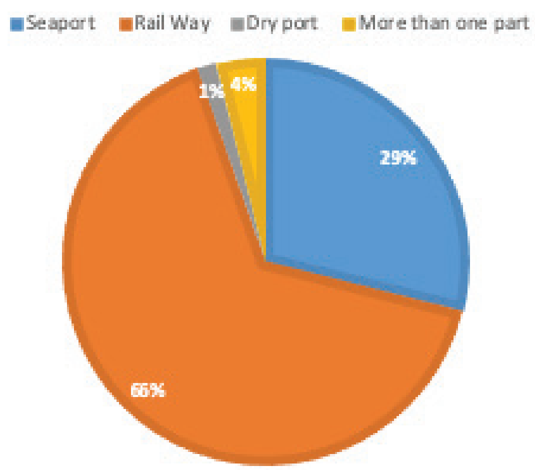

Figure 4.
Article distribution among the tree parts of seaport dry port system.

This result clearly shows a gap in treating risk management in the seaport dry port system, which represents one of the main reasons of working on this paper.

3.1.2. Risk Factors in the Seaport Dry Port System

Based on the 204 selected articles, we identified all the risk factors found, and we tried to classify them into different categories of risk factors: 1/ risk factors that can be caused by human factors, such as the lack of professional skills (Hsu, 2015), unsuitable reaction to errors (Pallis, 2017) or not following some procedures (Klockner and Toft, 2015); 2/ risk factors that can cause negative influence on the environment (Langella et al., 2016); 3/ risk factors that can be classified in the frame of security, such as smuggling (Loh et al., 2017; Pallis, 2017), terrorism attacks (A John et al., 2014; John et al., 2016; Loh et al., 2017) or other crimes (Joubert and Pretorius, 2017); 4/ natural risk factors such as floods (Pallis, 2017; Gou and Lam, 2018), strong cross wind (Yan et al., 2018) or earthquakes (A John et al., 2014; John et al., 2016; Pallis, 2017); 5/ organizational factors caused by the lack of good organization procedures like berth congestion (John et al., 2016; A John et al., 2014; Zhao et al., 2017; Wang and Guo, 2018) and storage area congestion (A John et al., 2014) (John et al., 2016) (Loh et al., 2017) (A. Kadir et al., 2020; Zhao et al., 2017); 6/ operational risk factors, which contain factors related to the operations of the seaport dry port system, such as failure of equipment (Klockner and Toft, 2015) or transportation good spillage (John et al., 2016); 7/ technical risk factors such as lack of equipment maintenance (John et al., 2014), and 8/ economic risk factors like commercial fraud (Tseng et al., 2015) oil price rise (Zhao et al., 2017).

Table 2.
Risks found in each part of the seaport dry port system.

	Seaport	Railway	Dry port
Human risk factors	Lack of professional skills Working concentration Misinterpretation of Instructions at workplace Safety culture/Climate Inadequate compliance of standards Sinking Unsuitable reaction to errors Not following instruction	Lack of professional skills Working concentration Misinterpretation of Instructions at workplace Safety culture/Climate Inadequate compliance of standards Impact of suicides on railway workers Unsuitable reaction on errors Not following instruction Level crossings/Pedestrian fatalities Risky driving behavior	Lack of professional skills Working concentration Misinterpretation of instructions at workplace Safety climate Inadequate compliance with standards Unsuitable reaction to errors Not following instruction
	(Hsu, 2015), (Loh et al., 2017), (Bergheim et al., 2015), (Pallis, 2017), (Arslan et al., 2016; Bellsolà Olba et al., 2020), (John et al., 2014), (John et al., 2016), (Klockner and Toft, 2015), (Klockner and Toft, 2015), (Laapotti, 2016), (Joubert and Pretorius, 2017), (Nayak et al., 2018), (Hani Tabai et al., 2018), (Klockner and Toft, 2015), (Hughes et al., 2018), (Cheng, 2019), (Gao et al., 2017), (Corrigan et al., 2018), (Curcuruto et al., 2018), (Klockner and Toft, 2015), (Bardon and Mishara, 2015), (Mishara and Bardon, 2017), (Laapotti, 2016), (Read et al., 2016), (Borsos et al., 2016), (Liang and Ghazel, 2018), (Bureika et al., 2017), (Liang et al., 2017), (Zhao et al., 2019), (M. Zhang et al., 2018), (Liang et al., 2018), (Wu and Zheng, 2018), (Djordjević et al., 2018), (Salmon et al., 2018), (Wang et al., 2016), (Skládaná et al., 2016), (Guo et al., 2016), (Mabrouk, 2016), (Klockner and Toft, 2015).		
Environment risk factors	Air pollution Noise pollution Chemical contaminants Grounded ship impact Salvage activities	Noise pollution Dangerous goods transportation effect on the environment Collision between train and animals	Air pollution Noise pollution Chemical contamination
	(Pallis, 2017; Sciarrillo et al., 2020), (He et al., 2015; Radziemska et al., 2020), (H. Zhang et al., 2018), (Bentaleb et al., 2015b; Huang et al., 2020c, 2020b), (Visintin et al., 2018), (Huang et al., 2020a).		

Security risk factors	Sabotage Vandalism Terrorism attacks Arson and purposed fire Illegal trade Illegal immigration Theft War Political instability Blockade Falsification of documents Hack of security system	Sabotage Vandalism Terrorism attacks Arson and purposed fire. Theft War Political instability Collision of trains (caused by other train)	Sabotage Vandalism Terrorism attacks Arson and purposed fire. Illegal trade Illegal immigration Theft War Political instability Blockade Falsification of documents Hack of security system
	(Matsika et al., 2016), (Bentaleb et al., 2015b), (John et al., 2014), (John et al., 2016), (Pallis, 2017), (Loh et al., 2017), (Leonard et al., 2015), (Chen et al., 2017; Yuan et al., 2020).		
Natural risk factors	Earthquakes Strong wind Heavy rain Fog Wave height Tide Hurricane and cyclone risk Floods High temperature during working hours Pandemic	Earthquakes - Strong wind Heavy rain Fog Hurricane and cyclone risk High temperature during work Pandemic Rock fall hazard	Earthquakes Strong wind Heavy rain Fog Hurricane and cyclone risk High temperature during working hours Pandemic
	(John et al., 2014), (John et al., 2016), (Pallis, 2017), (Pak et al., 2015), (Gou and Lam, 2018; McIntosh and Becker, 2020; Zhang and Lam, 2015), (Lam et al., 2017), (Chang et al., 2020; Zhu et al., 2020), (Yan et al., 2018), (Klockner and Toft, 2015), (Misnevs et al., 2015), (Wang et al., 2017), (Lagadec et al., 2018), (Binti Sa'adin et al., 2016), (Dindar et al., 2017), (Sanchis et al., 2020; Zaili Yang et al., 2018), (Bubeck et al., 2019), (Macciotta et al., 2017; Wang et al., 2020), (Alyami et al., 2019).		
Organizational risk factors	Storage area congestion Error in cargo handling and storage Lack of inspections and lack of monitoring and checking Poor change management Pressure and fatigue Strike Inadequate standards Poor error management Delivery of wrong container Berth congestion Lack of equipment Lack of standards	Poor change management Pressure and fatigue Strike Inadequate standards Poor error management Bad train scheduling.	Storage area congestion Error in cargo handling and storage Lack of inspections/Lack of monitoring and checking Poor change management Pressure and fatigue Strike Inadequate standards Poor error management Delivery of wrong container Lack of equipment Lack of standards
	(John et al., 2014), (John et al., 2016), (Loh et al., 2017), (Kadir et al., 2020; Zhao et al., 2017), (Pallis, 2017), (Zhisen Yang et al., 2018), (Hsu, 2015), (Morgan et al., 2016), (Filtness and Naweed, 2017), (Gong and Liu, 2020), (Wang and Guo, 2018), (Başhan et al., 2020), (Klockner and Toft, 2015), (Tsao et al., 2017), (Joubert and Pretorius, 2017), (Alyami et al., 2019), (Gong and Liu, 2020), (Sunaryo and Hamka, 2017), (Bentaleb et al., 2015b).		

Operational risk factors	Seaport equipment collision during operations Container damage Cargo waste Cargo/good damage during port loading/unloading Hazardous goods spill Seaport equipment failures during operations; worker death during operations. Worker injured during operations Vessels' collision Mooring operation failure	Container fall from trains Cargo waste during transportation Cargo/good damage during transportation Container damage during transportation Hazardous goods spill	Dry port equipment collision during operations Container damage Cargo waste Cargo/good damage during port loading/unloading Hazardous goods spill Dry port equipment failures during operations Worker death during operations Worker injured during operations
	(John et al., 2014), (Hsu, 2015), (Başhan et al., 2020; Cem Kuzu et al., 2019; Huang and van Gelder, 2020), (John et al., 2016), (Jiaguo Liu et al., 2019), (Tseng et al., 2015), (Pallis, 2017), (Hughes et al., 2018), (Macciotta et al., 2016), (van der Vlies et al., 2018), (Macciotta et al., 2018), (Zhao et al., 2019), (M. Zhang et al., 2018), (Huang et al., 2019), (Bentaleb et al., 2015b; Huang and Zhang, 2020), (Jintao Liu et al., 2019), (Hadj-Mabrouk, 2019; Klockner and Toft, 2015), (Sunaryo and Hamka, 2017), (Alyami et al., 2019), (Santarremigia et al., 2018), (Lagadec et al., 2018).		
Technical risk factors	Temporary stop of information systems caused by a technical failure Information delay Power outage Poor functioning of dry port equipment Poor lighting / visibility Seaport equipment breakdown Breakdown of seaport information systems Berth's length	Information delay Power outage Poor lighting/visibility Technical issues in railway turnout systems SPAD (Signal Passed at Danger) risk due to technical factors Derailment due to technical reasons Unavailable train (technical problems)	Temporary stop of information system caused by a technical failure Information delay Power outage Poor functioning of dry port equipment Poor lighting / visibility Breakdown of dry port equipment Breakdown of dry port information system
	(Zhao et al., 2017), (Pallis, 2017), (A John et al., 2014), (John et al., 2016), (Bentaleb et al., 2015b; Bolbot et al., 2020), (Loh et al., 2017), (Hsu, 2015), (Klockner and Toft, 2015), (Hughes et al., 2018), (Novales et al., 2019), (Naweed et al., 2015b), (Naweed et al., 2015a), (Madigan et al., 2016), (Binti Sa'adin et al., 2016), (Rashidy et al., 2018), (Filtness and Naweed, 2017), (Mabrouk, 2016), (Dindar et al., 2018b), (Kaeeni et al., 2018), (Liu et al., 2017; Singhal et al., 2020), (Dindar et al., 2018a), (Chang et al., 2015).		
Economic risk factors	Unexpected cost of evaluation and maintenance Global economic crises Commercial fraud Load / unload loss Economic loss due to natural hazards Customer refuses to pay Customer unable to pay	Unexpected cost of evaluation and maintenance Economic loss because of natural hazards	Unexpected cost of evaluation and maintenance Global economic transformations (crises) Commercial fraud Load / unload loss Economic loss due to natural hazard Customer refuses to pay Customer unable to pay
	(Bazaras and Palsaitis, 2017), (Tseng et al., 2015), (Filina-Dawidowicz et al., 2015), (Zaili Yang et al., 2018), (Wang et al., 2018), (Bentaleb et al., 2015b).		

3.2. Survey Method

3.2.1. Delphi Method Definition

The Delphi method is an iterative process designed to collect the decision-maker's judgment separately and anonymously in order to avoid negative or positive influences from the stronger members of the panel. We repeat this process until we finally reach a general group agreement (Figure 5).

Phase 1: Preparation - Initially, we identified the problem clearly in the Delphi technique, and we selected 12 decision-makers, 3 experts from each part of the studied system (seaport, rail, and dry port). Our criteria of selection were based on two simple conditions: 1) their functions should be related to the field, and 2) they should have at least 3 years of experience, which makes them competent to judge the identified risk factors. The selection was performed before preparing our questionnaire for the first round. This questionnaire should preferably contain open questions like "yes/no" or "agree/disagree"; questions may also include a rating scale.

Phase 2: Consultation - We started the distribution of the prepared questionnaire to the decision-makers separately. It is recommended to use the internet because it is expedient, practical, provides privacy and it is a low cost option. After the distribution of questionnaires, we regrouped and summarized the answers in one document and we also analyzed the results. Then, we started the second round with a question similar to the first questionnaire, but we included anonymously the results of the answers to the previous round with a scale of agreement with these included answers.

Phase 3: Consensus - This phase is based on the result of the consultation phase. We considered the level of agreement with this result and, if it was satisfying above 70%, we accepted it. If it was not, we regrouped the new answers and started a new round of questionnaires. We repeated this process until we reached the acceptable level of agreement or what we called "consensus". Finally, we prepared the final document with the result of the Delphi technique. The number of rounds of the Delphi method depends on the convergence of the judgments of the experts.

In our case, the application of the Delphi technic to the selected 12 experts guaranteed good evaluation and determination of the interaction between the different parts of the studied system, different categories of each part and different risk factors of each category. Moreover, for the distribution of questionnaires, we used the internet to ensure isolation and privacy.

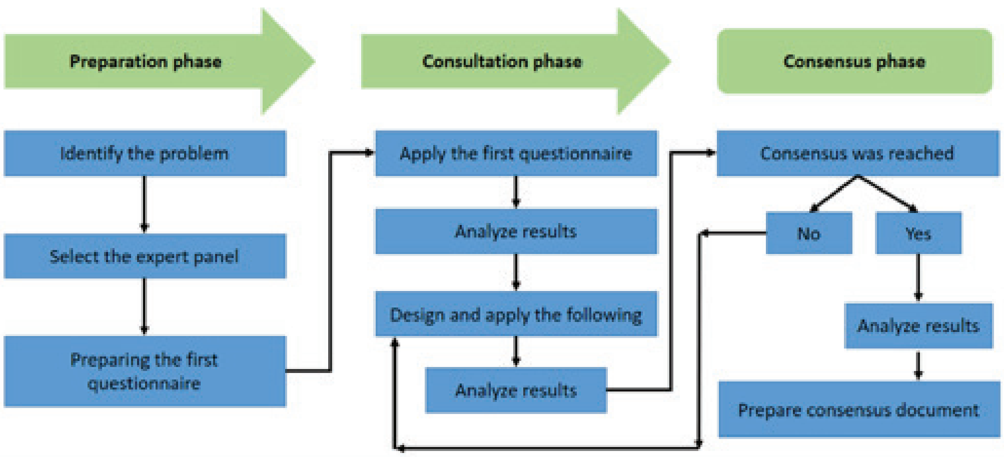

Figure 5.
Process of Delphi method based on 3 phases (Fernández-Ávila et al., 2020).

3.3. MCDM Method

3.3.1. The Fine Kinney Method Definition

The Fine Kinney method was developed by Kinney and Wiruth in 1976 in order to represent a quantitative tool for research in risk management domain (Kinney and Wiruth, 1976; Kokangül et al., 2017). In our paper, we consider four parameters to evaluate each risk factor: (F) Frequencies (frequencies of risk factors), (S) Severity (potential consequences of risk factors), (D) detectability (level of detection of risk factors), and (C) Controllability (if that risk factor happens, what level of control that we have is possible). Then, we calculated the risk score for every risk factor based on Eq (1).

$$\text{Eq (1): risk score} = F \cdot S \cdot D \cdot C \qquad (1)$$

In our study, the risk score came as a result of the MCDM method AHP, which evaluates (F) Frequencies, (S) Severity, (D) Detectability, and (C) Controllability of each risk factor based on our 12 experts' intuitive judgments as explained in the next section.

AHP definition

One of the major advantages of the AHP (Analytical Hierarchy Process) method is taking a complex problem and dividing it into a simple structure with several layers or categories (Lyu et al., 2020). Each layer is based on multiple criteria that are used to perform both qualitative and quantitative analyses (Kokangül et al., 2017; Saaty, 2008). The concept of the AHP is simple. Based on a defined scale, we take the qualitative intuitive judgments of the decision-makers and we define a quantitative priority for a given set of criteria (Al-Harbi, 2001).

Moreover, we calculate the consistency ratio (CR) of each set of criteria or each considered matrix of criteria. Saaty's consistency ratio is defined as consistency index (CI) / random index. The random index is formulated based on the number of criteria (n). The consistency index (CI) is presented in Eq (2), where λ_{max} is the largest eigenvalue of the considered matrix. The consistency ratio should be less than or equal to 10 percent. If it is greater than 10 Language editor says it is not English word.

percent, then the comparison matrix must be revised and the consistency ratio recalculated (Kokangül et al., 2017; Saaty, 2008).

$$Eq\ (2):\ CI = \frac{\lambda_{max} - n}{n - 1} \quad (2)$$

In our case, we used the AHP in order to achieve two points. The first point was organizing our tangible and intangible risk factors in a systematic way, which led us to a simple structure (Figure 6) of the seaport dry port system and its 3 major parts, each part containing 8 categories of risk factors (human risk factors, environmental risk factors, security risk factors, natural risk factors, organizational risk factors, operational risk factors, technical risk factors, and economic risk factors). For every category, we had a set of risk factors. The second point is scoring or weighing each part and categories in our system by their importance (Table 3) and evaluating each risk factor according to 4 criteria, (F) Frequencies (Table 4), (S) Severity (Table 5), (D) detectability (Table 6), and (C) Controllability (Table 7), based on intuitive judgments of the decision-makers.

After determining the values of importance of each part, category in the seaport dry port system, and the relative risk factors based on the AHP, using the scales shown in Tables 3–7, we applied the risk score equation Eq (1) to obtain the result shown in Table 8.

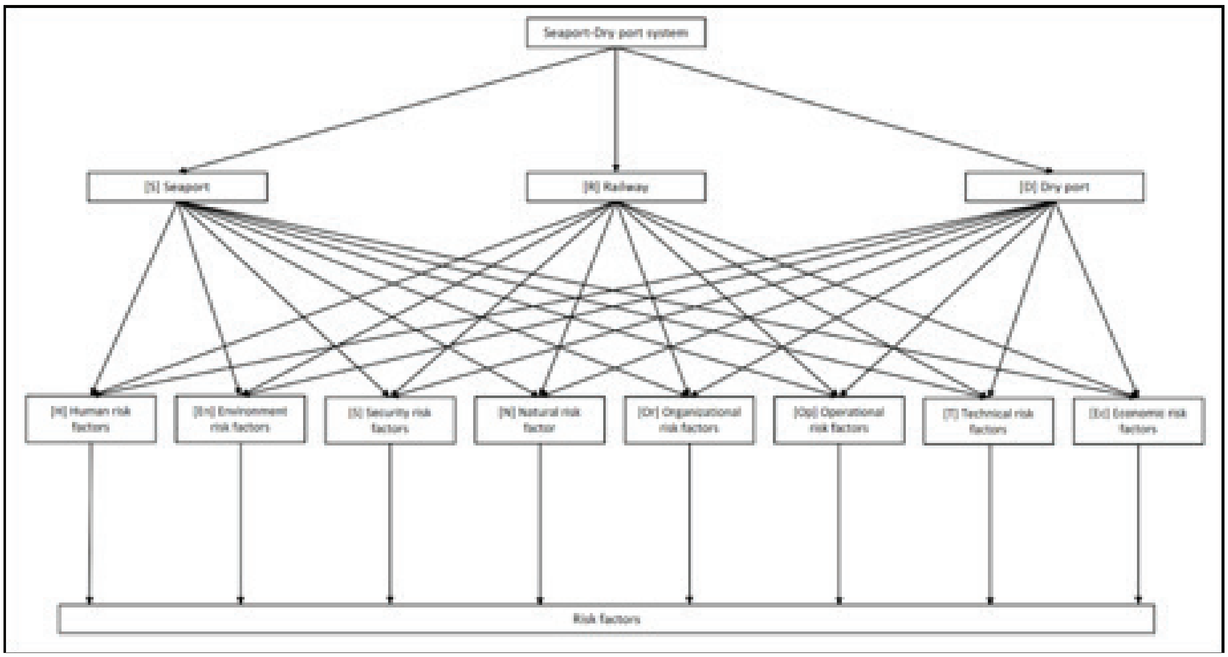

Figure 6t.
Structure of the studied system.

Table 3.
Scale used to compare the parts in terms of importance.

Importance	Value
Extreme importance of one over other	9
Very strong importance of one over other	7
Strong importance of one over other	5
Moderate importance of one over other	3
Equal importance	1
Intermediate values	2,4,6,8

Table 4.
Scale used to compare risk factors in terms of frequencies.

Frequencies	Value.
Continuous	9
Daily	8
More than one per week	7
Weekly	6
More than once per month	5
Monthly	4
A few per year	3
Yearly	2
Once in a few years	1

Table 5.
Scale used to compare risk factors in terms of severity.

Severity	Value
Many fatalities, or >$10^7 damage	9
A few fatalities, or >$10^6 damage	8
Fatality, or >$10^5 damage	7
Serious injury causing disability, or > $10^4 damage	6
Serious injury, or > $10^3 damage	5
Injury causing absence from work for more than one day, or > $500 damage	4
Injury causing absence from work for one day, or > $300 damage	3
Small injury or > $100 damage	2
Minor first aid accident, or > $50 Damage	1

Table 6.
Scale used to compare risk factors in terms of detectability.

Detectability	Value
No tool can detect it	9
Hardly detected by technology	8
Can be detected only by using technology	7
Hardly detected by humans	6
Moderated detection	5
Detectable	4
	3
Easy to detect	2
	1

Table 7.
Scale used to compare risk factors in terms of controllability.

Controllability	Value
Impossible to control	9
Hard to control	8
	7
Moderate control	6
	5
Controllable	4
	3
Easy to control	2
	1

Finally, we arrived to a phase where we had the risk score of each risk factor and the importance level of each category and each part of our studied system (Table 8), which gave us the capacity to analyze the impact level of the 3 parts of our system and the 8 categories of each part. However, the risk score here is limited only on the part treated, e.g., the risk score of [SH 1] - Lack of professional skills allows us to understand the impact level of [SH 1] only in the seaport part and not on all the seaport dry port system. To illustrate that, we used what we called the total risk score Eq (3) to give the impact level of each risk factor on all the seaport dry port system. Table 9 shows the top 10 risks that have the highest impact on all the seaport dry port system.

$$\text{Eq (3): Total risk score} = \text{Score of the part} \cdot \text{Score of the category} \cdot \text{Risk score of the risk factor} \quad (3)$$

Table 8.

Risk score of each risk factor and the importance level of each part and category.

	[S] Seaport (0.5396)	S	F	D	C	Risk score	[R] Railway (0.1634)	S	F	D	C	Risk score	[D] Dry port (0.2969)	S	F	D	C	Risk score
[H] Human risk factors (0.2808)	[SH 1] Lack of professional skills	0.0476	0.0691	0.0691	0.0376	8.55137 E-06	[RH 1] Lack of professional skills	0.0281	0.0749	0.0501	0.0294	3.09845 E-06	[DH 1] Lack of professional skills	0.0472	0.0687	0.0664	0.0534	1.15 E-05
	[SH 2] Working concentration	0.0853	0.2297	0.3114	0.0681	0.000415277	[RH 2] Working concentration	0.0487	0.2170	0.2109	0.0499	0.000111262	[DH 2] Working concentration	0.0829	0.2088	0.3298	0.0998	0.00057
	[SH 3] Misinterpretation of Instructions at Workplace	0.1228	0.3114	0.2297	0.2064	0.0018132	[RH 3] Misinterpretation of Instructions at Workplace	0.0687	0.2718	0.1674	0.1468	0.000458956	[DH 3] Misinterpretation of Instructions at Workplace	0.1406	0.3547	0.2377	0.1586	0.00188
	[SH 4] Safety climate	0.1661	0.0399	0.1231	0.2939	0.000239623	[RH 4] Safety climate	0.0919	0.0445	0.0915	0.2408	9.01094 E-05	[DH 4] Safety climate	0.2853	0.0402	0.1216	0.3192	0.000446
	[SH 5] Inadequate compliance of standards	0.0213	0.1748	0.1748	0.0681	4.43365 E-05	[RH 5] Inadequate compliance of standards	0.0140	0.1083	0.1307	0.0499	9.85893 E-06	[DH 5] Inadequate compliance of standards	0.0253	0.1778	0.1775	0.0998	7.96 E-05
	[SH 6] Sinking	0.3054	0.0223	0.0223	0.1122	1.71108 E-05	[RH 6] Impact of suicides on railway workers	0.1223	0.0875	0.2446	0.2130	0.000557688	[DH 6] Unsuitable reaction on errors	0.0280	0.1213	0.0393	0.1693	2.26 E-05
	[SH 7] Unsuitable reaction on errors	0.0292	0.1231	0.0399	0.1458	2.0883 E-05	[RH 7] Unsuitable reaction on errors	0.0182	0.1446	0.0313	0.0852	7.00421 E-06	[DH 7] Not following instruction	0.3907	0.0284	0.0278	0.0998	3.08 E-05
	[SH 8] Not following instruction	0.2223	0.0296	0.0296	0.0681	1.32757 E-05	[RH 8] Not following instructions	0.1682	0.0219	0.0217	0.0499	3.98828 E-06						
							[RH 9] Pedestrian fatalities / Level crossing accidents	0.2664	0.0175	0.0217	0.0852	8.62453 E-06						
							[RH 10] Risky driving behavior	0.1736	0.0120	0.0300	0.0400	2.49917 E-06						
[En] Environment risk factors (0.0224)	[SEn 1] Air pollution	0.1170	0.2353	0.0787	0.1003	0.000217147	[REn 1] Noise pollution	0.0751	0.7092	0.1340	0.1005	0.000716878	[DEn 1] Air pollution	0.1666	0.2430	0.0840	0.1005	0.000342
	[SEn 2] Noise pollution	0.0633	0.6076	0.0339	0.4890	0.000637393	[REn 2] Danger goods transportation	0.5917	0.0840	0.2609	0.4665	0.006049612	[DEn 2] Noise pollution	0.0938	0.7009	0.2109	0.4330	0.006005
	[SEn 3] Chemical contaminants	0.5354	0.0480	0.2983	0.2533	0.001943077	[REn 3] Collision between train and animals	0.3332	0.2068	0.6049	0.4330	0.018047712	[DEn 3] Chemical contamination	0.7396	0.0562	0.7049	0.4665	0.013657
	[SEn 4] Grounded ship impact	0.2210	0.0328	0.3900	0.0787	0.000222309												
	[SEn 5] Salvage activities	0.0633	0.0763	0.1991	0.0787	7.5713 E-05												

[S] Security risk factors (0.1639)	[SS 1] Sabotage	0.0308	0.0988	0.2799	0.0210	1.79295 E-05	[RS 1] Sabotage	0.0307	0.2806	0.3444	0.0250	7.41282 E-05	[DS 1] Sabotage	0.0302	0.0990	0.2797	0.0211	1.76 E-05
	[SS 2] Vandalism	0.0516	0.0784	0.0676	0.0352	9.62523 E-06	[RS 2] Vandalism	0.0528	0.1199	0.1952	0.0408	5.04427 E-05	[DS 2] Vandalism	0.0507	0.0765	0.0675	0.0353	9.23 E-06
	[SS 3] Terrorism attacks	0.1441	0.0225	0.0183	0.1977	1.1699 E-05	[RS 3] Terrorism attacks	0.1017	0.0539	0.0276	0.2177	3.29123 E-05	[DS 3] Terrorism attacks	0.1180	0.0225	0.0183	0.1983	9.62 E-06
	[SS 4] Arson and purposed fire.	0.0705	0.0988	0.0356	0.0764	1.89203 E-05	[RS 4] Arson and purposed fire.	0.0757	0.0754	0.0847	0.1142	5.52633 E-05	[DS 4] Arson and purposed fire.	0.0759	0.0990	0.0355	0.0766	2.04 E-05
	[SS 5] Illegal trade	0.0183	0.2343	0.1722	0.0532	3.9254 E-05	[RS 5] Theft	0.0201	0.3068	0.1066	0.0590	3.8744 E-05	[DS 5] Illegal trade	0.0178	0.2348	0.1721	0.0533	3.84 E-05
	[SS 6] Illegal immigration	0.0129	0.2343	0.1268	0.0532	2.03597 E-05	[RS 6] War	0.3369	0.0550	0.0428	0.3022	0.000239573	[DS 6] Illegal immigration	0.0125	0.2348	0.1267	0.0533	1.99 E-05
	[SS 7] Theft	0.0196	0.0988	0.0936	0.0532	9.63467 E-06	[RS 7] Political instability	0.2383	0.0786	0.1450	0.1595	0.000433038	[DS 7] Theft	0.0191	0.0990	0.0935	0.0533	9.45 E-06
	[SS 8] War	0.2388	0.0225	0.0221	0.2338	2.77342 E-05	[RS 8] Collision between trains (caused by other train)	0.1437	0.0300	0.0538	0.0816	1.89201 E-05	[DS 8] War	0.2315	0.0225	0.0221	0.2345	2.7 E-05
	[SS 9] Political instability	0.1891	0.0225	0.0510	0.1178	2.55238 E-05							[DS 9] Political instability	0.1855	0.0225	0.0513	0.1181	2.53 E-05
	[SS 10] Blockade	0.1091	0.0225	0.0338	0.0975	8.07864 E-06							[DS 10] Blockade	0.1323	0.0225	0.0342	0.0978	9.97 E-06
	[SS 11] Falsification of documents	0.0531	0.0381	0.0811	0.0329	5.39711 E-06							[DS 11] Falsification of documents	0.0590	0.0382	0.0810	0.0301	5.51 E-06
	[SS 12] Hack of security system	0.0619	0.0286	0.0180	0.0282	8.99518 E-07							[DS 12] Hack of security system	0.0674	0.0287	0.0180	0.0282	9.83 E-07
[N] Natural risk factors (0.0317)	[SN 1] Earthquakes	0.2254	0.0253	0.2990	0.2936	0.000499916	[RN 1] Earthquakes	0.3033	0.0326	0.3122	0.2900	0.000894152	[DN 1] Earthquakes	0.3967	0.0300	0.3622	0.3740	0.001612
	[SN 2] Strong wind	0.0846	0.1330	0.0632	0.0602	4.27949 E-05	[RN 2] Strong wind	0.1030	0.1174	0.0641	0.0742	5.75199 E-05	[DN 2] Strong wind	0.0920	0.1300	0.0641	0.0742	5.69 E-05
	[SN 3] Heavy rain	0.0558	0.1306	0.0632	0.0413	1.90316 E-05	[RN 3] Heavy rain	0.0638	0.1534	0.0590	0.0510	2.94573 E-05	[DN 3] Heavy rain	0.0593	0.1440	0.0641	0.0538	2.95 E-05
	[SN 4] Fog	0.0564	0.1760	0.1144	0.0956	0.000108451	[RN 4] Fog	0.0356	0.2086	0.1062	0.1049	8.26191 E-05	[DN 4] Fog	0.0593	0.2327	0.1062	0.1049	0.000154
	[SN 5] Wave height	0.0639	0.0902	0.0386	0.0602	1.3383 E-05	[RN 5] Hurricane and cyclones risk	0.1230	0.0773	0.1350	0.1300	0.000166763	[DN 5] Hurricane and cyclones risk	0.1270	0.0380	0.1350	0.1400	9.12 E-05
	[SN 6] Tide	0.0639	0.0678	0.0386	0.0602	1.00602 E-05	[RN 6] high temperature during work	0.0356	0.3090	0.0500	0.0378	2.07463 E-05	[DN 6] High temperature during work	0.0344	0.3975	0.0641	0.0378	3.31 E-05
	[SN 7] Hurricane and cyclones risk	0.1220	0.0231	0.1219	0.1212	4.16261 E-05	[RN 7] Pandemic	0.1958	0.0317	0.2043	0.2050	0.000260181	[DN 7] Pandemic	0.2313	0.0280	0.2043	0.2148	0.000284

	[SN 8] Floods	0.1220	0.0462	0.0386	0.0602	1.30946 E-05	[RN 8] Rock fall hazard	0.1300	0.0700	0.0700	0.1100	0.00007007						
	[SN 9] High Temperature during working hours	0.0298	0.2831	0.0632	0.0557	2.97553 E-05												
	[SN 10] Pandemic	0.1764	0.0247	0.1592	0.1519	0.000105196												
[Or] Organizational risk factors (0.1014)	[SOr 1] Gate congestion	0.1317	0.1596	0.0253	0.0512	2.72662 E-05	[ROr 1] Lack of monitoring and checking	0.0311	0.1000	0.0664	0.0455	9.38706 E-06	[DOr 1] Gate congestion	0.1468	0.1775	0.0267	0.0508	3.54 E-05
	[SOr 2] Storage area congestion	0.0720	0.0978	0.0454	0.0948	3.03078 E-05	[ROr 2] Poor change management	0.0521	0.2623	0.2377	0.1218	0.00039576	[DOr 2] Storage area congestion	0.0657	0.1088	0.0480	0.0939	3.22 E-05
	[SOr 3] Error in cargo handling and storage	0.0193	0.0708	0.0694	0.0297	2.82412 E-06	[ROr 3] Pressure and fatigue	0.0769	0.3748	0.0278	0.0823	6.60335 E-05	[DOr 3] Error in cargo handling and storage	0.0230	0.0787	0.0732	0.0295	3.91 E-06
	[SOr 4] Lack of inspections and lack of monitoring and checking	0.0946	0.0375	0.0454	0.0199	3.20689 E-06	[ROr 4] Strike	0.3680	0.0711	0.1216	0.2301	0.000731717	[DOr 4] Lack of inspections/Lack of monitoring and checking	0.0761	0.0417	0.0480	0.0197	3 E-06
	[SOr 5] poor change management	0.0314	0.0521	0.1197	0.0297	5.81534 E-06	[ROr 5] Inadequate standards	0.2159	0.0534	0.3298	0.3240	0.001230758	[DOr 5] Poor change management	0.0374	0.0579	0.1263	0.0295	8.06 E-06
	[SOr 6] Pressure and fatigue	0.0363	0.3026	0.0253	0.0199	5.52581 E-06	[ROr 6] Poor error management	0.1073	0.0852	0.1775	0.1686	0.000273348	[DOr 6] Pressure and Fatigue	0.0432	0.3365	0.0267	0.0197	7.65 E-06
	[SOr 7] Strike	0.2643	0.0155	0.0694	0.1388	3.94028 E-05	[ROr 7] Bad train scheduling	0.1487	0.0534	0.0393	0.0276	8.61433 E-06	[DOr 7] Strike	0.3147	0.0172	0.0732	0.1376	5.46 E-05
	[SOr 8] Inadequate standards	0.0693	0.0286	0.1289	0.2382	6.08932 E-05							[DOr 8] Inadequate standards	0.0761	0.0318	0.1361	0.2361	7.78 E-05
	[SOr 9] Poor error management	0.0193	0.0209	0.1007	0.0948	3.8635 E-06							[DOr 9] Poor error management	0.0229	0.0233	0.1063	0.0939	5.33 E-06
	[SOr 10] Deliver the wrong container.	0.0770	0.0209	0.2477	0.1759	7.0237 E-05							[DOr 10] Deliver the wrong container.	0.0740	0.0233	0.2614	0.1743	7.85 E-05
	[SOr 11] Berth congestion	0.0924	0.0968	0.0175	0.0446	7.00234 E-06							[DOr 11] Lack of equipment	0.0330	0.0714	0.0278	0.0265	1.74 E-06
	[SOr 12] Lack of equipment	0.0254	0.0645	0.0263	0.0268	1.15539 E-06							[DOr 12] Lack of standards	0.0871	0.0317	0.0463	0.0885	1.13 E-05
	[SOr 13] Lack of standards	0.0670	0.0323	0.0789	0.0357	6.09204 E-06												

[Op] Operational risk factors (0.0682)	[SOp 1] Seaport equipment collision during operations	0.1121	0.0509	0.0309	0.0544	9.59413 E-06	[ROp 1] Containers Fall from train	0.1368	0.1722	0.0465	0.0835	9.15632 E-05	[DOp 1] Dry Port equipment collision during operations	0.1409	0.0550	0.0324	0.0600	1.51 E-05
	[SOp 2] Container damage	0.0191	0.2596	0.0541	0.0984	2.64334 E-05	[ROp 2] Cargo waste during transportation	0.0828	0.1525	0.2258	0.0490	0.000139819	[DOp 2] Container damage	0.0238	0.2810	0.0557	0.0440	1.64 E-05
	[SOp 3] Cargo waste	0.0330	0.1392	0.1647	0.0223	1.68369 E-05	[ROp 3] Cargo/good damage during transportation	0.0581	0.1637	0.3734	0.1392	0.000494067	[DOp 3] Cargo waste	0.0420	0.1486	0.1700	0.0700	7.42 E-05
	[SOp 4] Cargo/ good damage during port loading/ unloading	0.0251	0.1971	0.2455	0.0223	2.70612 E-05	[ROp 4] Container damage during transportation	0.0408	0.4791	0.1285	0.1704	0.000428014	[DOp 4] Cargo/ good damage during port loading/ unloading	0.0317	0.2117	0.2648	0.0560	9.96 E-05
	[SOp 5] Hazardous goods spilling	0.3210	0.0214	0.1647	0.3162	0.000357507	[ROp 5] Hazardous goods spilling	0.6815	0.0324	0.2258	0.5579	0.002782771	[DOp 5] Hazardous goods spilling	0.3827	0.0237	0.1760	0.3526	0.000562
	[SOp 6] Seaport equipment failures during operations	0.0444	0.0924	0.1207	0.1449	7.17394 E-05							[DOp 6] Dry Port equipment failures during operations	0.0567	0.0989	0.1258	0.1602	0.000113
	[SOp 7] Worker death during operations.	0.1958	0.0297	0.0843	0.1911	9.38155 E-05							[DOp 7] Worker death during operational operations.	0.2415	0.0328	0.0871	0.2192	0.000151
	[SOp 8] Worker injured during operations	0.0633	0.1392	0.0843	0.0324	2.41251 E-05							[DOp 8] Worker injured during operational operations	0.0807	0.1486	0.0871	0.0385	4.03 E-05
	[SOp 9] Vessel collision	0.1121	0.0409	0.0309	0.0884	1.25343 E-05												
	[SOp 10] Mooring operation fails	0.0741	0.0296	0.0196	0.0296	1.27324 E-06												
[T] Technical risk factors (0.0452)	[ST 1] Stopping temporary of information system caused by a technical	0.0393	0.0847	0.1831	0.0443	2.70152 E-05	[RT 1] Information delay.	0.0210	0.4066	0.3490	0.1487	0.000442581	[DT 1] Stopping temporary of information system caused by a technical	0.0451	0.0928	0.1888	0.0502	3.97 E-05
	[ST 2] Information delay	0.0239	0.3523	0.3432	0.0791	0.000228851	[RT 2] Power outage	0.2359	0.1036	0.0336	0.2394	0.000196858	[DT 2] Information delay.	0.0274	0.3840	0.3666	0.0874	0.000337
	[ST 3] Power outage	0.2889	0.0246	0.0697	0.2385	0.000118364	[RT 3] Poor Lighting visibility.	0.0325	0.2499	0.0752	0.0952	5.80969 E-05	[DT 3] Power outage	0.3217	0.0281	0.0711	0.0931	5.99 E-05

	[ST 4] Poor functioning of dry port equipment	0.1017	0.2215	0.1761	0.1380	0.000547504	[RT 4] Technical issue in railway turnout systems	0.1389	0.0566	0.0644	0.0952	4.82145 E-05	[DT 4] Poor functioning of dry port equipment	0.1149	0.2414	0.1802	0.1606	0.000802
	[ST 5] Poor lighting visibility	0.0697	0.1507	0.0979	0.0819	8.42737 E-05	[RT 5] SPAD (Signal Passed at Danger) risk duo to technical factors	0.0548	0.1236	0.2322	0.0526	8.26957 E-05	[DT 5] Poor lighting visibility	0.0815	0.1630	0.0994	0.0912	0.000121
	[ST 6] Seaport equipment breakdown	0.1547	0.0479	0.0484	0.1479	5.30358 E-05	[RT 6] Derailment due to technic reasons	0.3250	0.0249	0.1869	0.3382	0.000510739	[DT 6] Dry port equipment breakdown	0.1658	0.0520	0.0469	0.2262	9.14 E-05
	[ST 7] Breakdown of seaport information system	0.2156	0.0477	0.0484	0.2385	0.000118856	[RT 7] Unavailable train (technical problems)	0.1920	0.0348	0.0587	0.0307	1.2013 E-05	[DT 7] Breakdown of dry port information system	0.2436	0.0381	0.0469	0.2913	0.000127
	[ST 8] The berth's length	0.1061	0.0705	0.0332	0.0318	7.91009 E-06												
[Ec] Economic risk factors (0.2863)	[SEc 1] Unexpected Cost of evaluation and maintenance	0.0455	0.3691	0.2208	0.0328	0.000121923	[REc 1] Unexpected Cost of evaluation and maintenance	0.1667	0.8571	0.1250	0.1111	0.00198412	[DEc 1] Unexpected Cost of evaluation and maintenance	0.0455	0.3691	0.2208	0.0328	0.000122
	[SEc 2] Global economic transformations. (crises)	0.2301	0.0440	0.0517	0.2269	0.000118857	[REc 2] Economic loss because natural hazard	0.8333	0.1429	0.8750	0.8889	0.092592261	[DEc 2] Global economic transformations (crises)	0.2301	0.0440	0.0517	0.2269	0.000119
	[SEc 3] Commercial fraud	0.1686	0.1111	0.3893	0.1639	0.001195067							[DEc 3] Commercial fraud	0.1686	0.1111	0.3893	0.1639	0.001195
	[SEc 4] Load / Unload loss	0.1218	0.1521	0.1220	0.1161	0.000262556							[DEc 4] Load / Unload loss	0.1218	0.1521	0.1220	0.1161	0.000263
	[SEc 5] Economic loss because natural hazard	0.3240	0.0306	0.0517	0.3218	0.000164899							[DEc 5] Economic loss because natural hazard	0.3240	0.0306	0.0517	0.3218	0.000165
	[SEc 6] Customer refuses to pay	0.0823	0.0747	0.0823	0.0827	4.18175 E-05							[DEc 6] Customer refuse to pay	0.0823	0.0747	0.0823	0.0827	4.18 E-05
	[SEc 7] Customer unable to pay	0.0280	0.2183	0.0823	0.0557	2.80087 E-05							[DEc 7] Customer unable to pay	0.0276	0.2183	0.0823	0.0557	2.76 E-05

Table 9.
Top 10 risk factors in all the seaport dry port system.

Risk factor	Total risk score
[REc 2]	0,004331597
[SH 3]	0,000274735
[SEc 3]	0,000184623
[DH 3]	0,000156735
[DEc 3]	0,000101578
[REc 1]	9,282 E-05
[DEn 3]	9,08267 E-05
[REn 3]	6,60575 E-05
[SH 2]	6,29226 E-05
[DH 2]	4,75206 E-05

4. DISCUSSION:

To deal with the complexity of the studied system, the proposed framework allowed us first to identify the potential risk factors of the seaport dry port system using seven-step SLR, which led us to 204 well selected and examined articles with an average of 60 risk factors in the seaport part, the rail part, and the dry port part. Beside the identification of risk factors, we illustrated the division of the found articles across the three major parts, and we found out that we had only 1% of the articles dealing with the dry port part, which was logical due to the novelty of the concept and the steady development of research topics on the dry port concept. Therefore, it confirmed the importance of this study in this period of dry port concept development (Khaslavskaya and Roso, 2020; Lamii et al., 2020; Witte et al., 2019); Secondly, it allowed us to present a systematic structure using the AHP (Figure 6) to simplify the presentation of such a complex system in order to facilitate and organize our next steps of extracting data and scoring risk factors. Thirdly, we distributed questionnaires to our 12 chosen experts. Usually, in a normal meeting, we face a known issue of having an expert with a strong personality or position, who dominates the meeting and influences other experts. To avoid this issue, we used the Delphi technique (Figure 5), which guaranteed anonymity, and led to a total agreement on the intuitive judgments needed to evaluate Frequencies, Severity, Detectability, and Controllability of each risk factor. In addition, we also evaluated the importance level of each part and category in the studied system. Fourthly, we calculated the risk score Eq (1) of each risk factor, which gave us an idea about the risk factor impact on each part of the seaport dry port system (seaport, rail, or dry port). Moreover, we calculated the total risk score Eq (3), which provided the impact of each risk factor on all the seaport dry port system and not just in one of its 3 parts. The original use of the MCDM AHP method (Harker and Vargas, 1987; Saaty, 1977) was oriented to comparing different alternatives based on multiple criteria. In our presented framework, we used the AHP in the opposite way, we scored the parts of seaport dry port system, categories of risk factors, and risk factors in order to allow the decision-makers to precisely detect the worst possible scenarios using the result provided.

5. CONCLUSION

This study comes as a result of an early work (Lamii et al., 2020), which proved that one of the less treated issues in the seaport dry port system was risk management, and of the huge positive impact of the studied system that can be produced technically, socially, environmentally, and economically (Bentaleb et al., 2015a; Witte et al., 2019). Therefore, we decided to fill this gap in this paper. The result of this study will help decision-makers and practitioners in two stages: first, to have a global idea about the potential risk factors in the seaport, rail, and dry port; second, to facilitate the assessment of the found risk factors and prioritize them based on the risk score if they work on just one of the 3 parts, or the total risk score if the context of work is only the seaport dry port system. The advantage of the proposed framework is simplicity and ease of its application for practitioners to any similar system no matter if the problem treated is risk management, localization management (Black et al., 2018), performance management or any topic with multiple criteria decision-making frame. This study also represents a reference for any researcher who wants to raise the risk management issue in the seaport dry port system to the next level using the AI (artificial intelligence) algorithms as a part of the Fourth Industrial Revolution.

CONFLICT OF INTEREST

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

REFERENCES

Kadir, Z. et al., 2020. Risk Management Framework for Handling and Storage of Cargo at Major Ports in Malaysia towards Port Sustainability. Sustainability, 12(2), p.516. Available at: http://dx.doi.org/10.3390/su12020516.

Al-Harbi, K.M.A.-S., 2001. Application of the AHP in project management. International Journal of Project Management, 19(1), pp.19–27. Available at: http://dx.doi.org/10.1016/s0263-7863(99)00038-1.

Alyami, H. et al., 2019. Advanced uncertainty modelling for container port risk analysis. Accident Analysis & Prevention, 123, pp.411–421. Available at: http://dx.doi.org/10.1016/j.aap.2016.08.007.

Arslan, V. et al., 2016. Safety Culture Assessment and Implementation Framework to Enhance Maritime Safety. Transportation Research Procedia, 14, pp.3895–3904. Available at: http://dx.doi.org/10.1016/j.trpro.2016.05.477.

Bardon, C. & Mishara, B.L., 2015. Development of a Comprehensive Programme to Prevent and Reduce the Negative Impact of Railway Fatalities, Injuries and Close Calls on Railway Employees. Journal of Occupational Rehabilitation, 25(3), pp.557–568. Available at: http://dx.doi.org/10.1007/s10926-014-9562-1.

Başhan, V., Demirel, H. & Gul, M., 2020. An FMEA-based TOPSIS approach under single valued neutrosophic sets for maritime risk evaluation: the case of ship navigation safety. Soft Computing, 24(24), pp.18749–18764. Available at: http://dx.doi.org/10.1007/s00500-020-05108-y.

Bazaras, D. & Palsaitis, R., 2017. Factors of Emergency Situations Risks Management in the BSR Ports. Procedia Engineering, 178, pp.501–506. Available at: http://dx.doi.org/10.1016/j.proeng.2017.01.094.

Bellsolà Olba, X. et al., 2019. Risk Assessment Methodology for Vessel Traffic in Ports by Defining the Nautical Port Risk Index. Journal of Marine Science and Engineering, 8(1), p.10. Available at: http://dx.doi.org/10.3390/jmse8010010.

Bentaleb, F., Mabrouki, C. & Semma, A., 2015a. Dry Port Development: A Systematic Review. Journal of ETA Maritime Science, 3(2), pp.75–96. Available at: http://dx.doi.org/10.5505/jems.2015.98608.

Bentaleb, F., Mabrouki, C. & Semma, A., 2015b. A Multi-Criteria Approach for Risk Assessment of Dry Port-Seaport System. Supply Chain Forum: An International Journal, 16(4), pp.32–49. Available at: http://dx.doi.org/10.1080/16258312.2015.11728692.

Van den Berg, R. & De Langen, P.W., 2014. Towards an "inland terminal centred" value proposition. Maritime Policy & Management, 42(5), pp.499–515. Available at: http://dx.doi.org/10.1080/03088839.2014.928955.

Bergheim, K. et al., 2015. The relationship between psychological capital, job satisfaction, and safety perceptions in the maritime industry. Safety Science, 74, pp.27–36. Available at: http://dx.doi.org/10.1016/j.ssci.2014.11.024.

Binti Sa'adin, S., Kaewunruen, S. & Jaroszweski, D., 2016. Risks of Climate Change with Respect to the Singapore-Malaysia High Speed Rail System. Climate, 4(4), p.65. Available at: http://dx.doi.org/10.3390/cli4040065.

Black, J. et al., 2018. Issues in Dry Port Location and Implementation in Metropolitan Areas: The Case of Sydney, Australia. Transactions on Maritime Science, 7(1), pp.41–50. Available at: http://dx.doi.org/10.7225/toms.v07.n01.004.

Bolbot, V. et al., 2020. A novel cyber-risk assessment method for ship systems. Safety Science, 131, p.104908. Available at: http://dx.doi.org/10.1016/j.ssci.2020.104908.

Borsos, A., Gabor, M. & Koren, C., 2016. Safety Ranking of Railway Crossings in Hungary. Transportation Research Procedia, 14, pp.2111–2120. Available at: http://dx.doi.org/10.1016/j.trpro.2016.05.226.

Bubeck, P. et al., 2019. Global warming to increase flood risk on European railways. Climatic Change, 155(1), pp.19–36. Available at: http://dx.doi.org/10.1007/s10584-019-02434-5.

Bureika, G. et al., 2016. Modelling the assessment of traffic risk at level crossings of Lithuanian railways. Transport, 32(3), pp.282–290. Available at: http://dx.doi.org/10.3846/16484142.2016.1244114.4.

Cem Kuzu, A., Akyuz, E. & Arslan, O., 2019. Application of Fuzzy Fault Tree Analysis (FFTA) to maritime industry: A risk analysing of ship mooring operation. Ocean Engineering, 179, pp.128–134. Available at: http://dx.doi.org/10.1016/j.oceaneng.2019.03.029.

Chang, C.-H., Xu, J. & Song, D.-P., 2015. Risk analysis for container shipping: from a logistics perspective. The International Journal of Logistics Management, 26(1), pp.147–171. Available at: http://dx.doi.org/10.1108/ijlm-07-2012-0068.

Chang, L. et al., 2020. Hybrid belief rule base for regional railway safety assessment with data and knowledge under uncertainty. Information Sciences, 518, pp.376–395. Available at: http://dx.doi.org/10.1016/j.ins.2019.12.035.

Chen, H., Cullinane, K. & Liu, N., 2017. Developing a model for measuring the resilience of a port-hinterland container transportation network. Transportation Research Part E: Logistics and Transportation Review, 97, pp.282–301. Available at: http://dx.doi.org/10.1016/j.tre.2016.10.008.

Cheng, Y.-H., 2017. Railway safety climate: a study on organizational development. International Journal of Occupational Safety and Ergonomics, 25(2), pp.200–216. Available at: http://dx.doi.org/10.1080/10803548.2017.1361591.

Corrigan, S. et al., 2019. Human factors and safety culture: Challenges and opportunities for the port environment. Safety Science, 119, pp.252–265. Available at: http://dx.doi.org/10.1016/j.ssci.2018.03.008.

Curcuruto, M. et al., 2018. Multilevel safety climate in the UK rail industry: A cross validation of the Zohar and Luria MSC scale. Safety Science, 110, pp.183–194. Available at: http://dx.doi.org/10.1016/j.ssci.2018.02.008.

Dindar, S., Kaewunruen, S. & An, M., 2016. Identification of appropriate risk analysis techniques for railway turnout systems. Journal of Risk Research, 21(8), pp.974–995. Available at: http://dx.doi.org/10.1080/13669877.2016.1264452.

Dindar, S. et al., 2018. Bayesian Network-based probability analysis of train derailments caused by various extreme weather patterns on railway turnouts. Safety Science, 110, pp.20–30. Available at: http://dx.doi.org/10.1016/j.ssci.2017.12.028.

Dindar, S., Kaewunruen, S. & Sussman, J.M., 2017. Climate Change Adaptation for GeoRisks Mitigation of Railway Turnout Systems. Procedia Engineering, 189, pp.199–206. Available at: http://dx.doi.org/10.1016/j.proeng.2017.05.032.

Djordjević, B., Krmac, E. & Mlinarić, T.J., 2018. Non-radial DEA model: A new approach to evaluation of safety at railway level crossings. Safety Science, 103, pp.234–246. Available at: http://dx.doi.org/10.1016/j.ssci.2017.12.001.

Fernández-Ávila, D.G., Rojas, M.X. & Rosselli, D., 2020. The Delphi method in rheumatology research: are we doing it right? Revista Colombiana de Reumatología (English Edition), 27(3), pp.177–189. Available at: http://dx.doi.org/10.1016/j.rcreue.2019.04.007.

Filina-Dawidowicz, L., Iwańkowicz, R. & Rosochacki, W., 2015. Risk measures of load loss during service of refrigerated containers in seaports. Archives of Transport, 34(2), pp.19–27. Available at: http://dx.doi.org/10.5604/08669546.1169208.

Filtness, A.J. & Naweed, A., 2017. Causes, consequences and countermeasures to driver fatigue in the rail industry: The train driver perspective. Applied Ergonomics, 60, pp.12–21. Available at: http://dx.doi.org/10.1016/j.apergo.2016.10.009.

Gao, Q. et al., 2017. Violation causes from the perspectives of managers and workers in Chinese railway systems: An exploratory study. Safety Science, 94, pp.41–51. Available at: http://dx.doi.org/10.1016/j.ssci.2017.01.001.

Gong, Z. & Liu, N., 2019. Mitigative and adaptive investments for natural disasters and labor strikes in a seaport–dry port inland logistics network. Maritime Policy & Management, 47(1), pp.92–108. Available at: http://dx.doi.org/10.1080/03088839.2019.1675195.

Gou, X. & Lam, J.S.L., 2018. Risk analysis of marine cargoes and major port disruptions. Maritime Economics & Logistics, 21(4), pp.497–523. Available at: http://dx.doi.org/10.1057/s41278-018-0110-3.

Guo, M. et al., 2016. The impact of personality on driving safety among Chinese high-speed railway drivers. Accident Analysis & Prevention, 92, pp.9–14. Available at: http://dx.doi.org/10.1016/j.aap.2016.03.014.

Hadj-Mabrouk, H., 2019. Contribution of Artificial Intelligence to Risk Assessment of Railway Accidents. Urban Rail Transit, 5(2), pp.104–122. Available at: http://dx.doi.org/10.1007/s40864-019-0102-3.

Hanaoka, S. & Regmi, M.B., 2011. Promoting intermodal freight transport through the development of dry ports in Asia: An environmental perspective. IATSS Research, 35(1), pp.16–23. Available at: http://dx.doi.org/10.1016/j.iatssr.2011.06.001.

Hani Tabai, B. et al., 2018. Evaluating the impact of train drivers' cognitive and demographic characteristics on railway accidents. Safety Science, 110, pp.162–167. Available at: http://dx.doi.org/10.1016/j.ssci.2018.03.027.

Harker, P.T. & Vargas, L.G., 1987. The Theory of Ratio Scale Estimation: Saaty's Analytic Hierarchy Process. Management Science 33, pp.1383–1403. Available at: https://doi.org/10.1287/mnsc.33.11.1383.

He, G. et al., 2015. Environmental risks of high-speed railway in China: Public participation, perception and trust. Environmental Development, 14, pp.37–52. Available at: http://dx.doi.org/10.1016/j.envdev.2015.02.002.

Hirst, P., Thompson, G., Bromley, S., 2009. Globalization in Question (3rd edition). Polity, Cambridge, UK / Malden, MA, USA.

Hopkins, A., 2011. Risk-management and rule-compliance: Decision-making in hazardous industries. Safety Science, 49(2), pp.110–120. Available at: http://dx.doi.org/10.1016/j.ssci.2010.07.014.

Hsu, W.-K.K., 2014. Assessing the Safety Factors of Ship Berthing Operations. Journal of Navigation, 68(3), pp.576–588. Available at: http://dx.doi.org/10.1017/s0373463314000861.

Huang, W. et al., 2020a. Fault Tree and Fuzzy D-S Evidential Reasoning combined approach: An application in railway dangerous goods transportation system accident analysis. Information Sciences, 520, pp.117–129. Available at: http://dx.doi.org/10.1016/j.ins.2019.12.089.

Huang, W. et al., 2019. A systematic railway dangerous goods transportation system risk analysis approach: The 24 model. Journal of Loss Prevention in the Process Industries, 61, pp.94–103. Available at: http://dx.doi.org/10.1016/j.jlp.2019.05.021.

Huang, W. et al., 2020b. Risk state changes analysis of railway dangerous goods transportation system: Based on the cusp catastrophe model. Reliability Engineering & System Safety, 202, p.107059. Available at: http://dx.doi.org/10.1016/j.ress.2020.107059.

Huang, W. & Zhang, Y., 2021. Railway Dangerous Goods Transportation System Risk Assessment: An Approach Combining FMEA With Pessimistic–Optimistic Fuzzy Information Axiom Considering Acceptable Risk Coefficient. IEEE Transactions on Reliability, 70(1), pp.371–388. Available at: http://dx.doi.org/10.1109/tr.2020.2973431.

Huang, W. et al., 2020c. Using an expanded Safety Failure Event Network to analyze railway dangerous goods transportation system risk-accident. Journal of Loss Prevention in the Process Industries, 65, p.104122. Available at: http://dx.doi.org/10.1016/j.jlp.2020.104122.

Huang, Y. & van Gelder, P.H.A.J.M., 2020. Collision risk measure for triggering evasive actions of maritime autonomous surface ships. Safety Science, 127, p.104708. Available at: http://dx.doi.org/10.1016/j.ssci.2020.104708.

Hughes, P. et al., 2018. From free-text to structured safety management: Introduction of a semi-automated classification method of railway hazard reports to elements on a bow-tie diagram. Safety Science, 110, pp.11–19. Available at: http://dx.doi.org/10.1016/j.ssci.2018.03.011.

Jeevan, J. et al., 2019. A Procedure for Implementing Exploratory Mixed Methods Research into Dry Port Management. Transactions on Maritime Science, 8(2), pp.157–170. Available at: http://dx.doi.org/10.7225/toms.v08.n02.001.

John, A. et al., 2014a. An integrated fuzzy risk assessment for seaport operations. Safety Science, 68, pp.180–194. Available at: http://dx.doi.org/10.1016/j.ssci.2014.04.001.

John, A et al., 2014b. A new approach for evaluating the disruption risks of a seaport system, in: Nowakowski, T., Młyńczak, M., Jodejko-Pietruczuk, A., Werbińska-Wojciechowska, S. (Eds.), Safety and Reliability: Methodology and Applications. CRC Press, pp. 591–598. https://doi.org/10.1201/b17399-83.

John, A. et al., 2016. A risk assessment approach to improve the resilience of a seaport system using Bayesian networks. Ocean Engineering, 111, pp.136–147. Available at: http://dx.doi.org/10.1016/j.oceaneng.2015.10.048.

Joubert, F.J. & Pretorius, L., 2017. Using Monte Carlo simulation to create a ranked check list of risks in a portfolio of railway construction projects. South African Journal of Industrial Engineering, 28(2). Available at: http://dx.doi.org/10.7166/28-2-1604.

Kaeeni, S., Khalilian, M., Mohammadzadeh, J., 2018. Derailment accident risk assessment based on ensemble classification method. Safety Science, Railway safety 110, 3–10. https://doi.org/10.1016/j.ssci.2017.11.006.

Kaeeni, S., Khalilian, M. & Mohammadzadeh, J., 2018. Derailment accident risk assessment based on ensemble classification method. Safety Science, 110, pp.3–10. Available at: http://dx.doi.org/10.1016/j.ssci.2017.11.006.

Khaslavskaya, A. & Roso, V., 2020. Dry ports: research outcomes, trends, and future implications. Maritime Economics & Logistics, 22(2), pp.265–292. Available at: http://dx.doi.org/10.1057/s41278-020-00152-9.

Kinney, G.F., Wiruth, A.D., 1976. Practical risk analysis for safety management. Naval Weapons Center China Lake CA.

Klockner, K. & Toft, Y., 2015. Accident Modelling of Railway Safety Occurrences: The Safety and Failure Event Network (SAFE-Net) Method. Procedia Manufacturing, 3, pp.1734–1741. Available at: http://dx.doi.org/10.1016/j.promfg.2015.07.487.

Kokangül, A., Polat, U. & Dağsuyu, C., 2017. A new approximation for risk assessment using the AHP and Fine Kinney methodologies. Safety Science, 91, pp.24–32. Available at: http://dx.doi.org/10.1016/j.ssci.2016.07.015.

Laapotti, S., 2016. Comparison of fatal motor vehicle accidents at passive and active railway level crossings in Finland. IATSS Research, 40(1), pp.1–6. Available at: http://dx.doi.org/10.1016/j.iatssr.2015.12.003.

Lagadec, L.-R. et al., 2018. A surface runoff mapping method for optimizing risk assessment on railways. Safety Science, 110, pp.253–267. Available at: http://dx.doi.org/10.1016/j.ssci.2018.05.014.

Lam, J.S.L., Liu, C. & Gou, X., 2017. Cyclone risk mapping for critical coastal infrastructure: Cases of East Asian seaports. Ocean & Coastal Management, 141, pp.43–54. Available at: http://dx.doi.org/10.1016/j.ocecoaman.2017.02.015.

Lamii, N. et al., 2020. Systematic Review of Literature on Dry Port Concept Evolution. Transactions on Maritime Science, 9(2). Available at: http://dx.doi.org/10.7225/toms.v09.n02.009.

Langella, G. et al., 2016. Marine Engines Emission and Dispersion in Fuel Switching Operation: A Case Study for the Port of Naples. Energy Procedia, 101, pp.368–375. Available at: http://dx.doi.org/10.1016/j.egypro.2016.11.047.

Lättilä, L., Henttu, V. & Hilmola, O.-P., 2013. Hinterland operations of sea ports do matter: Dry port usage effects on transportation costs and CO2 emissions. Transportation Research Part E: Logistics and Transportation Review, 55, pp.23–42. Available at: http://dx.doi.org/10.1016/j.tre.2013.03.007.

Leonard, T.J., Gallo, P. & Véronneau, S., 2015. Security challenges in United States sea ports: an overview. Journal of Transportation Security, 8(1-2), pp.41–49. Available at: http://dx.doi.org/10.1007/s12198-015-0155-9.

Li, W., Hilmola, O.-P. & Panova, Y., 2019. Container Sea Ports and Dry Ports: Future CO2 Emission Reduction Potential in China. Sustainability, 11(6), p.1515. Available at: http://dx.doi.org/10.3390/su11061515.

Liang, C. & Ghazel, M., 2017. A risk assessment study on accidents at French level crossings using Bayesian belief networks. International Journal of Injury Control and Safety Promotion, 25(2), pp.162–172. Available at: http://dx.doi.org/10.1080/17457300.2017.1416480.

Liang, C. et al., 2018. Developing accident prediction model for railway level crossings. Safety Science, 101, pp.48–59. Available at: http://dx.doi.org/10.1016/j.ssci.2017.08.013.

Liang, C. et al., 2017. Risk analysis on level crossings using a causal Bayesian network based approach. Transportation Research Procedia, 25, pp.2167–2181. Available at: http://dx.doi.org/10.1016/j.trpro.2017.05.418.

Liu, J. et al., 2019. Understanding railway operational accidents using network theory. Reliability Engineering & System Safety, 189, pp.218–231. Available at: http://dx.doi.org/10.1016/j.ress.2019.04.030.

Liu, J., Zhou, H. & Sun, H., 2019. A three-dimensional risk management model of port logistics for hazardous goods. Maritime Policy & Management, 46(6), pp.715–734. Available at: http://dx.doi.org/10.1080/03088839.2019.1627435.

Liu, X., Rapik Saat, M. & Barkan, C.P.L., 2017. Freight-train derailment rates for railroad safety and risk analysis. Accident Analysis & Prevention, 98, pp.1–9. Available at: http://dx.doi.org/10.1016/j.aap.2016.09.012.

Loh, H.S. et al., 2017. Fuzzy comprehensive evaluation of port-centric supply chain disruption threats. Ocean & Coastal Management, 148, pp.53–62. Available at: http://dx.doi.org/10.1016/j.ocecoaman.2017.07.017.

Lovrić, I., Bartulović, D. & Steiner, S., 2020. Influence of Dry Port Establishment on Regional Development Through Regional Development Index. Transactions on Maritime Science, 9(2). Available at: http://dx.doi.org/10.7225/toms.v09.n02.012.

Lyu, H.-M. et al., 2020. Inundation risk assessment of metro system using AHP and TFN-AHP in Shenzhen. Sustainable Cities and Society, 56, p.102103. Available at: http://dx.doi.org/10.1016/j.scs.2020.102103.

Mabrouk, H.H., 2016. "CLASCA": Learning System for Classification and Capitalization of Accident Scenarios of Railway. Journal of Engineering Research and Application 6, pp. 91–98.

Mabrouki, C., Bentaleb, F. & Mousrij, A., 2014. A decision support methodology for risk management within a port terminal. Safety Science, 63, pp.124–132. Available at: http://dx.doi.org/10.1016/j.ssci.2013.09.015.

Macciotta, R. et al., 2017. Rock fall hazard control along a section of railway based on quantified risk. Georisk: Assessment and Management of Risk for Engineered Systems and Geohazards, 11(3), pp.272–284. Available at: http://dx.doi.org/10.1080/17499518.2017.1293273.

Macciotta, R. et al., 2015. Quantitative risk assessment of slope hazards along a section of railway in the Canadian Cordillera—a methodology considering the uncertainty in the results. Landslides, 13(1), pp.115–127. Available at: http://dx.doi.org/10.1007/s10346-014-0551-4.

Macciotta, R. et al., 2018. Hazard ranking for railway transport of dangerous goods in Canada. Case Studies on Transport Policy, 6(1), pp.43–50. Available at: http://dx.doi.org/10.1016/j.cstp.2017.11.006.

Madigan, R., Golightly, D. & Madders, R., 2016. Application of Human Factors Analysis and Classification System (HFACS) to UK rail safety of the line incidents. Accident Analysis & Prevention, 97, pp.122–131. Available at: http://dx.doi.org/10.1016/j.aap.2016.08.023.

Matsika, E. et al., 2016. Development of Risk Assessment Specifications for Analysing Terrorist Attacks Vulnerability on Metro and Light Rail Systems. Transportation Research Procedia, 14, pp.1345–1354. Available at: http://dx.doi.org/10.1016/j.trpro.2016.05.207.

McIntosh, R.D. & Becker, A., 2020. Applying MCDA to weight indicators of seaport vulnerability to climate and extreme weather impacts for U.S. North Atlantic ports. Environment Systems and Decisions, 40(3), pp.356–370. Available at: http://dx.doi.org/10.1007/s10669-020-09767-y.

Mishara, B.L. & Bardon, C., 2017. Characteristics of railway suicides in Canada and comparison with accidental railway fatalities: Implications for prevention. Safety Science 91, pp. 251–259. Available at: https://doi.org/10.1016/j.ssci.2016.06.017.

Misnevs, B., Melikyan, A. & Bazaras, D., 2015. Hazard Assessment of Weather Factors for the Occurrence of an Emergency on the Railway. Procedia Computer Science, 77, pp.40–47. Available at: http://dx.doi.org/10.1016/j.procs.2015.12.357.

Morgan, J.I. et al., 2016. UK rail workers' perceptions of accident risk factors: An exploratory study. International Journal of Industrial Ergonomics 55, pp.103–113. Available at: https://doi.org/10.1016/j.ergon.2016.08.003.

Naweed, A., Rainbird, S. & Chapman, J., 2015. Investigating the formal countermeasures and informal strategies used to mitigate SPAD risk in train driving. Ergonomics, 58(6), pp.883–896. Available at: http://dx.doi.org/10.1080/00140139.2014.1001448.

Naweed, A., Rainbird, S. & Dance, C., 2015. Are you fit to continue? Approaching rail systems thinking at the cusp of safety and the apex of performance. Safety Science, 76, pp.101–110. Available at: http://dx.doi.org/10.1016/j.ssci.2015.02.016.

Nayak, S., Tripathy, S. & Dash, A., 2018. Role of non technical skill in human factor engineering: a crucial safety issue in Indian Railway. International Journal of System Assurance Engineering and Management, 9(5), pp.1120–1136. Available at: http://dx.doi.org/10.1007/s13198-018-0715-z.

Novales, M., Bertrand, D. & Fontaine, L., 2019. A proposed new approach to light rail safety management in Spain and other countries. Safety Science, 118, pp.740–751. Available at: http://dx.doi.org/10.1016/j.ssci.2019.06.010.

Pak, J.-Y. et al., 2015. Port safety evaluation from a captain's perspective: The Korean experience. Safety Science, 72, pp.172–181. Available at: http://dx.doi.org/10.1016/j.ssci.2014.09.007.

Pallis, P.L., 2017. Port Risk Management in Container Terminals. Transportation Research Procedia, 25, pp.4411–4421. Available at: http://dx.doi.org/10.1016/j.trpro.2017.05.337.

Radziemska, M. et al., 2020. Environmental impact assessment of risk elements from railway transport with the use of pollution indices, a biotest and bioindicators. Human and Ecological Risk Assessment: An International Journal, 27(2), pp.517–540. Available at: http://dx.doi.org/10.1080/10807039.2020.1736984.

Rashidy, R.A.H.E.L. et al., 2018. A big data modeling approach with graph databases for SPAD risk. Safety Science, 110, pp.75–79. Available at: http://dx.doi.org/10.1016/j.ssci.2017.11.019.

Read, G.J.M. et al., 2016. Walking the line: Understanding pedestrian behaviour and risk at rail level crossings with cognitive work analysis. Applied Ergonomics, 53, pp.209–227. Available at: http://dx.doi.org/10.1016/j.apergo.2015.10.004.

Roso, V., 2007. Evaluation of the dry port concept from an environmental perspective: A note. Transportation Research Part D: Transport and Environment, 12(7), pp.523–527. Available at: http://dx.doi.org/10.1016/j.trd.2007.07.001.

Roso, V., Russell, D. & Rhoades, D., 2019. Diffusion of Innovation Assessment of Adoption of the Dry Port Concept. Transactions on Maritime Science, 8(1), pp.26–36. Available at: http://dx.doi.org/10.7225/toms.v08.n01.003.

Roso, V., Woxenius, J. & Lumsden, K., 2009. The dry port concept: connecting container seaports with the hinterland. Journal of Transport Geography, 17(5), pp.338–345. Available at: http://dx.doi.org/10.1016/j.jtrangeo.2008.10.008.

Saaty, T.L., 2008. Decision making with the analytic hierarchy process. International Journal of Services Sciences 1, pp.83–98. Available at: https://doi.org/10.1504/IJSSci.2008.01759.

Saaty, T.L., 1977. A scaling method for priorities in hierarchical structures. Journal of Mathematical Psychology, 15(3), pp.234–281. Available at: http://dx.doi.org/10.1016/0022-2496(77)90033-5.

Salmon, P.M. et al., 2018. STAMP goes EAST: Integrating systems ergonomics methods for the analysis of railway level crossing safety management. Safety Science, 110, pp.31–46. Available at: http://dx.doi.org/10.1016/j.ssci.2018.02.014.

Sanchis, I.V. et al., 2020. Risk of increasing temperature due to climate change on operation of the Spanish rail network. Transportation Research Procedia, 45, pp.5–12. Available at: http://dx.doi.org/10.1016/j.trpro.2020.02.056.

Santarremigia, F.E. et al., 2018. Railway safety by designing the layout of inland terminals with dangerous goods connected with the rail transport system. Safety Science, 110, pp.206–216. Available at: http://dx.doi.org/10.1016/j.ssci.2018.03.001.

Sciarrillo, R. et al., 2020. Contamination and ecological risk assessment of the seaport of Naples (Italy): Insights from marine sediments. Journal of Geochemical Exploration, 210, p.106449. Available at: http://dx.doi.org/10.1016/j.gexplo.2019.106449.

Singhal, V. et al., 2020. Artificial Intelligence Enabled Road Vehicle-Train Collision Risk Assessment Framework for Unmanned Railway Level Crossings. IEEE Access, 8, pp.113790–113806. Available at: http://dx.doi.org/10.1109/access.2020.3002416.

Skládaná, P. et al., 2016. Trespassing Railway Property – Typology of Risk Localities. Transportation Research Procedia, 14, pp.2091–2100. Available at: http://dx.doi.org/10.1016/j.trpro.2016.05.224.

Sunaryo & Hamka, M.A., 2017. Safety Risks Assessment on Container Terminal Using Hazard Identification and Risk Assessment and Fault Tree Analysis Methods. Procedia Engineering, 194, pp.307–314. Available at: http://dx.doi.org/10.1016/j.proeng.2017.08.150.

Tsao, L., Chang, J. & Ma, L., 2017. Fatigue of Chinese railway employees and its influential factors: Structural equation modelling. Applied Ergonomics, 62, pp.131–141. Available at: http://dx.doi.org/10.1016/j.apergo.2017.02.021.

Tsao, Y.-C. & Thanh, V.-V., 2019. A multi-objective mixed robust possibilistic flexible programming approach for sustainable seaport-dry port network design under an uncertain environment. Transportation Research Part E: Logistics and Transportation Review, 124, pp.13–39. Available at: http://dx.doi.org/10.1016/j.tre.2019.02.006.

Tseng, W.-J., Ding, J.-F. & Li, M.-H., 2013. Risk management of cargo damage in export operations of ocean freight forwarders in Taiwan. Proceedings of the Institution of Mechanical Engineers, Part M: Journal of Engineering for the Maritime Environment, 229(3), pp.232–247. Available at: http://dx.doi.org/10.1177/1475090213513755.

UNCTAD, 2018. Review of maritime transport.

Van der Vlies, V., Berrevoets, M. & Tretjakova, D., 2018. Back on track: Creating a robust institutional framework for rail transport of hazardous substances in the Netherlands. Safety Science, 110, pp.242–252. Available at: http://dx.doi.org/10.1016/j.ssci.2017.10.002.

Visintin, C. et al., 2018. Managing the timing and speed of vehicles reduces wildlife-transport collision risk. Transportation Research Part D: Transport and Environment, 59, pp.86–95. Available at: http://dx.doi.org/10.1016/j.trd.2017.12.003.

Wang, G. et al., 2017. A Bayesian network model for prediction of weather-related failures in railway turnout systems. Expert Systems with Applications, 69, pp.247–256. Available at: http://dx.doi.org/10.1016/j.eswa.2016.10.011.

Wang, L. et al., 2018. A Risk-Based Maintenance Decision-Making Approach for Railway Asset Management. International Journal of Software Engineering and Knowledge Engineering, 28(04), pp.453–483. Available at: http://dx.doi.org/10.1142/s0218194018400065.

Wang, W.-D., Li, J. & Han, Z., 2019. Comprehensive assessment of geological hazard safety along railway engineering using a novel method: a case study of the Sichuan-Tibet railway, China. Geomatics, Natural Hazards and Risk, 11(1), pp.1–21. Available at: http://dx.doi.org/10.1080/19475705.2019.1699606.

Wang, X. et al., 2016. Non-crossing rail-trespassing crashes in the past decade: A spatial approach to analyzing injury severity. Safety Science, 82, pp.44–55. Available at: http://dx.doi.org/10.1016/j.ssci.2015.08.017.

Wang, Z. & Guo, C., 2018. Minimizing the risk of seaport operations efficiency reduction affected by vessel arrival delay. Industrial Management & Data Systems, 118(7), pp.1498–1509. Available at: http://dx.doi.org/10.1108/imds-12-2017-0563.

Wide, P. & Roso, V., 2021. Information on Resource Utilisation for Operational Planning in Port Hinterland Transport. Transactions on Maritime Science, 10(2), pp.477–487. Available at: http://dx.doi.org/10.7225/toms.v10.n02.w02.

Witte, P., Wiegmans, B. & Ng, A.K.Y., 2019. A critical review on the evolution and development of inland port research. Journal of Transport Geography, 74, pp.53–61. Available at: http://dx.doi.org/10.1016/j.jtrangeo.2018.11.001.

Wu, D. & Zheng, W., 2018. Formal model-based quantitative safety analysis using timed Coloured Petri Nets. Reliability Engineering & System Safety, 176, pp.62–79. Available at: http://dx.doi.org/10.1016/j.ress.2018.03.035.

Yan, N., Chen, X. & Li, Y., 2018. Assessment of overturning risk of high-speed trains in strong crosswinds using spectral analysis approach. Journal of Wind Engineering and Industrial Aerodynamics, 174, pp.103–118. Available at: http://dx.doi.org/10.1016/j.jweia.2017.12.024.

Yang, Z. et al., 2018. Risk and cost evaluation of port adaptation measures to climate change impacts. Transportation Research Part D: Transport and Environment, 61, pp.444–458. Available at: http://dx.doi.org/10.1016/j.trd.2017.03.004.

Yang, Zhisen et al., 2018. A risk-based game model for rational inspections in port state control. Transportation Research Part E: Logistics and Transportation Review, 118, pp.477–495. Available at: http://dx.doi.org/10.1016/j.tre.2018.08.001.

Yuan, T. et al., 2020. Identification of the main risks for international rail construction projects based on the effects of cost-estimating risks. Journal of Cleaner Production, 274, p.122904. Available at: http://dx.doi.org/10.1016/j.jclepro.2020.122904.

Zhang, H. et al., 2018. A risk assessment based optimization method for route selection of hazardous liquid railway network. Safety Science, Railway safety 110, pp.217–229. Available at: https://doi.org/10.1016/j.ssci.2018.04.003.

Zhang, M. et al., 2018. A comparative study of rail-pedestrian trespassing crash injury severity between highway-rail grade crossings and non-crossings. Accident

Analysis & Prevention, 117, pp.427–438. Available at: http://dx.doi.org/10.1016/j.aap.2018.02.001.

Zhang, Y. & Lam, J.S.L., 2015. Estimating the economic losses of port disruption due to extreme wind events. Ocean & Coastal Management, 116, pp.300–310. Available at: http://dx.doi.org/10.1016/j.ocecoaman.2015.08.009.

Zhao, S., Iranitalab, A. & Khattak, A.J., 2018. A clustering approach to injury severity in pedestrian-train crashes at highway-rail grade crossings. Journal of Transportation Safety & Security, 11(3), pp.305–322. Available at: http://dx.doi.org/10.1080/19439962.2018.1428257.

Zhao, X., Yan, H. & Zhang, J., 2016. A critical review of container security operations. Maritime Policy & Management, 44(2), pp.170–186. Available at: http://dx.doi.org/10.1080/03088839.2016.1253883.

Zhu, W. et al., 2020. Seismic Risk Assessment of the Railway Network of China's Mainland. International Journal of Disaster Risk Science, 11(4), pp.452–465. Available at: http://dx.doi.org/10.1007/s13753-020-00292-9.