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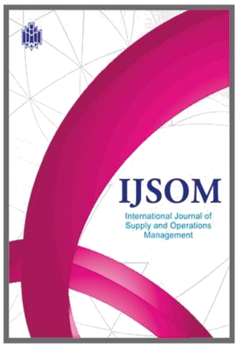

Multimodal Container Ttransportation Ttraceability and Supply Chain Risk Management: A Review of Methods and Solutions

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Abstract

Containerization has revolutionized international freight transport. It makes possible to optimize port handling operations and offers multimodality. In addition, the construction of increasingly large container vessels allows economies of scale while smart logistics thanks to the development of the Internet of Things, increase companies' flexibility and responsiveness. However, international multimodal transportation is subject to random events (risks) and suffers from lack of visibility which severely impacts the entire supply chain. In order to deal with these problems, research has been carried out in the field of supply chain risk management and the literature has been widely populated. This work deals with multimodal container supply chain risk management using traceability and visibility Data. The main objective of this paper is to analyze proposed solutions to improve the supply chains efficiency by acting on risk management in containers transportation, highlighting literature gaps and providing future research directions. Finally, a specific approach for real-time management of shipments by taking into account random events is proposed.

Keywords: Smart container; Traceability; Risk management; multimodal container transportation.

1. **Introduction**

Container transport has revolutionized international freight transport, containerization makes it possible to optimize port handling operations and offers multimodality. In addition, construction of increasingly large container vessels allows economies of scale. Container multimodal transportation consists of transporting the container from the departure warehouse to the final warehouse using different transport means (Figure 1) (combination of road rail and maritime transport). Multimodal transportation is one of the key factors of globalization, it represents 90% of international trades (Fruth and Teuteberg 2017). In 2018, 160 millions of Twenty-foot Equivalent Unit (TEUs) were transported by container and world traffic in containerized goods increased by 6.4% per year (Ouedraogo et al. 2020). The increase in the volume of containers transported and the multitude of actors involved in the transport process makes it become more and more complex and dynamic. Multimodal and international container transportation can involve more than twenty actors(Ouedraogo et al. 2020), this study focuses on the four main actors (shipper, shipping line, container terminal and inland carrier):

- The shipper is the company or legal person who owns the transported products.
- The shipping line is the company that deals with the maritime transport of containers.
- The carrier is the company that deals with inland container transportation.
- The Container terminal" plays an instrumental role in the movement of containerized cargo from consignor to consignee. Containers are intermodal by definition, and the terminals are the place where they change transportation modes" (UNECE, United Nations, 2020).

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Container transportation is always being affected by hazardous events that can severely impact supply chain. During shipment, containers are exposed to risk events such as thief, mishandling, condition variation, extreme weather. These events impact all stakeholders of the supply chain by causing delays, deterioration of products quality and enormous financial losses. Containers can often transport very sensitive products with high market values (foods, drugs, luxury products, etc.). These products must be transported under very specific conditions and having visibility at each stage of the transport process limits the impact of risks associated with the deterioration of the products quality and products delivery delays. For example, the recent pandemic world crisis caused a disruption in multimodal transportation. Disruptions due to multimodal supply chain risks have impacted the performances of the companies (Aboubakar Ouedraogo et al. 2020), this is why the multimodal supply chain risk management receives a great deal of attention in the literature (Agamez-Arias and Moyano-Fuentes 2017; Bălan 2020; Dua and Sinha 2019; L. Fan, Wilson, et Dahl 2012). These last year's many research (Longo, Mirabelli, and Tremori 2009; Tran, Dobrovnik, and Kummer 2018; Heilig and Voß 2017; Mar-Ortiz, Gracia, and Castillo-García 2018; Sahnoun and Maamri 2015) have been published on supply chain risk management. These works offer solutions based on different techniques to optimize the risk management of multimodal transportation. Indeed, the development of technologies, Internet of Things and availability of vessel tracking data (AIS data) offer new possibilities in terms of traceability, visibility and enables to increase the performance of the supply chain. Internet of things permits to track containers by using Intelligent tracking technologies. A large number of technological and scientific solutions have been developed to track and trace containers in order to deal with risks encountered during shipments. The main objective of this paper is to conduct a review of multimodal supply chain risk management techniques and tools. In order to achieve article goals, the following research question will be answering:

- What methods and solutions have been proposed in the literature for improving container supply chain risk management?
- What kind of data do these solutions use?

To address these questions, the survey will focus on the solutions of the state of the art that fulfill specific features that could implemented in a decision support system for supply chain decision-makers. This paper is structured in 5 sections and is based on the existing literature related to multimodal container supply chain risk management between 2000 and 2020. After defining the supply chain risk management and traceability topic in multimodal transportation, section three presents the research methodology use to carry out this literature review. Based on this, section four presents the selected above-mentioned features and details the analysis of the conducted literature review. Finally, a future approach to improve container supply chain risk management will be discussed in section five.

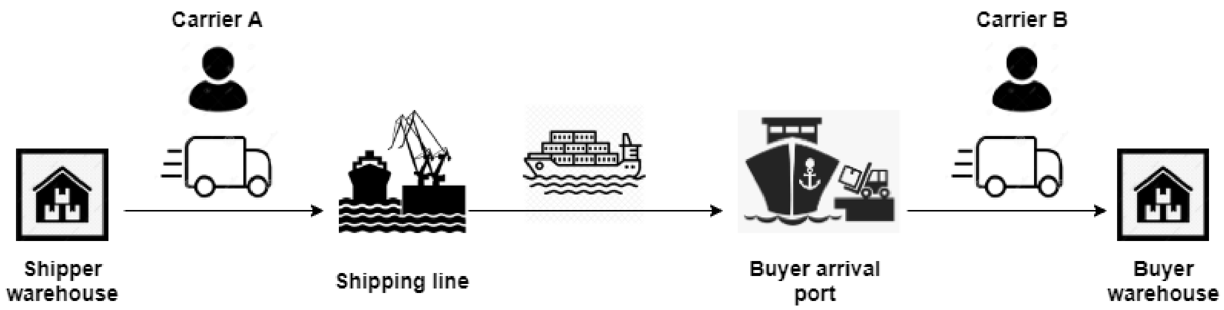

Figure 1. Multimodal transportation process

2. Multimodal transportation supply chain risk management and traceability

" Supply chain is a network of facilities that assures the functions of supply of raw materials, their transformation into components and finished products, and distribution of finished products to customers" (Lee 1993). Supply chain management can be defined as operations related to the supply chain, which take account flow management (physical and information), inventory management and supplier management. Multimodal container transportation is essential in an international supply chain. In fact, containerization facilitates the change of transportation mode and ensures the integrity of transported products. That is why, the works carried out on the multimodal container transportation topic often inherit form those conducted in supply chain management._The aim of this section is to analyze relevant knowledge to this review. Definition of important concepts will also be provided.

2.1. Supply chain risk

Many authors in the literature have attempted to give a definition for risk. The ISO31000 (« ISO - ISO 31000 — Risk Management » s. d.) standard defines risk as the effect of uncertainty on objectives. A risk can be defined as "the possibility that an event may occur whose occurrence would have impact (positive or negative) on the progress of the activity"(Gourc, 2006.)." Literature on supply chain risk management defines risk as purely negative and leading to undesired results or consequences" (J. Vilko, Ritala, and Hallikas 2019). A common definition of supply chain risk is the product R = P * I, where P is the probability of occurrence and I is defined as the consequence of this event on supply chain.

2.2. Multimodal container supply chain management

Multimodal container transportation is exposed to various hazardous events that affect the supply chain of all the stakeholders involved in the transportation process. Disruptions due to multimodal container supply chain risks have impacted the performances of the companies. Supply chain risk management aims to manage risk presents in supply chain. As the risk definition, there is no common definition of Supply Chain Risk Management (SCRM) in literature (Marquès 2010) but the researchers agreed on four most important steps in SCRM that are:

1. Risk Identification: the purpose of risk identification is to build a list of potential risks with their sources and their impact area. It can use classic tools such as: historical data, theoretical analyzes, opinions from experts and other competent people, brainstorming (Marquès 2010). The works carried out in the risk identification on multimodal container transportation allow to define typologies and classes of risk. The authors in (Ouedraogo et al. 2020) proposed a classification of risks according to the nature of the flows. The proposed classes are summarized in Table 1.
2. Risk Assessment: it makes it possible to express quantitatively or qualitatively the probability of occurrence and consequences of each of the risks identified in step one. Conventionally, this step consists in establishing the level of risk, i.e. the importance of the risk. The goal is to provide a framework allowing to compare the risks and to distinguish those which will have to be treated from the others, on the basis of decision criteria (Marquès 2010).
3. Risk Treatment: the process of risk treatment involves choosing a solution to address the risk and its implementation (Marquès 2010). Risk treatment can be broken down into several possible strategies: (a) anticipating the risk, (b) avoiding the risk, (c)dealing with its consequences or (d) sharing the risk.

    a) Anticipating risk consists of putting in place a strategy that allows to predict its occurrence.
    b) Avoiding the risk involves applying a strategy to bypass the area where the risk event occurs. For example, in the container supply chain, it will be a question of choosing a route to bypass a road where pirates are acting.
    c) Dealing with risk consequences consists of putting in place measures that prevent the risk of negatively impacting activities. For example, for a company that works with just in time methods and imports its material, it is to have stock available even in case of transportation delays.
    d) Sharing the risk consists of sharing risk consequences with another party, for example shipper takes out a high insurance policy for sensitive products in order to minimize the financial loss on the supply chain.

4. Risk Monitoring involves monitoring the level of risk to ensure that it remains at a manageable level.

Starting from this step, SCRM can be characterized by its ability to identify first all the risks present in the supply chain, then evaluate and propose mitigation strategies in order to assess these risks. And finally SCRM is also be characterize by risks monitoring in order to ensure that risks stay within an acceptable level.

Table 1. Risk class

Risk class	Risk events
Supply risk	Congestion, Labor strike, Fire…
Demand risk	Unexpected customer demand
Business risk	Fuel cost, Taxes changes, storage cost…
Environmental risk	Natural disaster, political conflict, uncertainty weather…
Organizational risk	Inappropriate planning estimation…
Infrastructural risk	Lack of visibility, lack of transportation mode…

2.3. Traceability and visibility in multimodal container transportation supply chain

The large number of actors involved in the container transportation process reduces supply chain visibility and makes it difficult to manage uncertainties (risk events). In addition, due to the heterogeneity of information systems, the traceability of shipments is not complete. However, traceability and visibility are the bases of risk management in multimodal container transport (J. Vilko, Ritala, and Hallikas 2019). Indeed, the integration of traceability and visibility data makes it possible to offer better risk assessment solutions according to the actors involved in the supply chain and the decision-making context. The following parts define traceability and visibility and then show their importance in multimodal container supply chain risk management.

2.3.1. Traceability in multimodal container transportation supply chain

According to ISO 9000-2005, traceability is defined as" the ability to determine the history, use or location of a specific entity". Traceability is essential in transportation and distribution of temperature sensitive products. For example, in drugs industry and cold chain industry, traceability of transportation is mandatory. It ensures the quality of transported products by keeping track of the crossing points. Definition of traceability depends on the studies context. Thus, in this paper, container traceability will be defined as the ability to follow and monitor the movements of a container and trace back information from its internal and external environment.

2.3.2. Visibility in multimodal container transportation supply chain

Supply chain visibility can be defined as" the extent to which actors within a supply chain have access to or share information which they consider as key or useful to their operation and which they consider will be of mutual benefit" (Papert, Rimpler, and Pflaum 2016). Supply chain visibility allows supply chain stakeholders to follow shipments in near real-time. (J. Vilko, Ritala, and Hallikas 2019) argue that visibility is one the key of risk management. Supply chain visibility provides transparency during container shipment, It's also provide productivity and effective planning (J. P. P. Vilko and Hallikas 2012). One solution proposed to improve multimodal container transportation visibility is smart container. It is a normal container booster with technology to enable real-time tracking and locating of the container. Smart container ensures the following feature (Papert, Rimpler, and Pflaum 2016):

- Container identification
- Container locating
- Sensors (temperature, accelerometer…)
- Data transmission to supply chain actors
- Traceability data storage

2.4. Risk management Framework

Figure 2 presents the framework in which risks are addressed in multimodal container transport on this 3 axes: (1) Traceability/ Visibility, (2) Supply Chain Actors, (3) Decision-making level. The Traceability / visibility axis makes it possible to define the type of data required according to the risk management step, the supply chain actors' axis list supply chain stakeholders affected by risk. The decision-making level axis makes it possible to define the context in which supply chain actor place themselves for risk treatment. Decision-making level is made up of the different decision levels found in the decision process, (1) Strategic decision, (2) Tactical decision and (3) Operational decision.

1. Strategic decisions: Strategic decisions engages decision-makers for a long period (more than 5 years)(S. Wattanakul et al. 2019). These kind of decisions are taken by the highest hierarchical level and they are occasional.
2. Tactical decisions: Tactical decisions engages decision-makers over the medium term (2 to 5 years). These decisions are frequently taken by senior managers. These decisions are not frequent and unpredictable.
3. Operational decisions: Operational decisions are short term decision (less than two years). These decisions are made by the performers. These decisions are frequent, very predictable.

Solution choice for risk treatment strongly depends on the actors involved in the transportation process and the risk class encountered during container transportation. The Table 2 which is inspired by the work of (S. Wattanakul et al. 2019) classifies the risk class according to the different decision levels for the actors considered in this study. For example, for the shipping line, the risks associated with business (fuel cost, storage cost) and the environment (natural disaster) are identified and dealt with at a strategic level. The Figure 3 gives relation between these 3 axis and general risk management step. In fact, the risk identification depends on the actor involved in the transport process and on his decision level. The risk assessment depends on the actor decision level and the data available. Likewise, risk monitoring strongly depends on the actor involved in the transportation process and on the data available. The treatment of the risk, when it comes to it, strongly depends on the actors of the transportation process, their decision level and the data available.

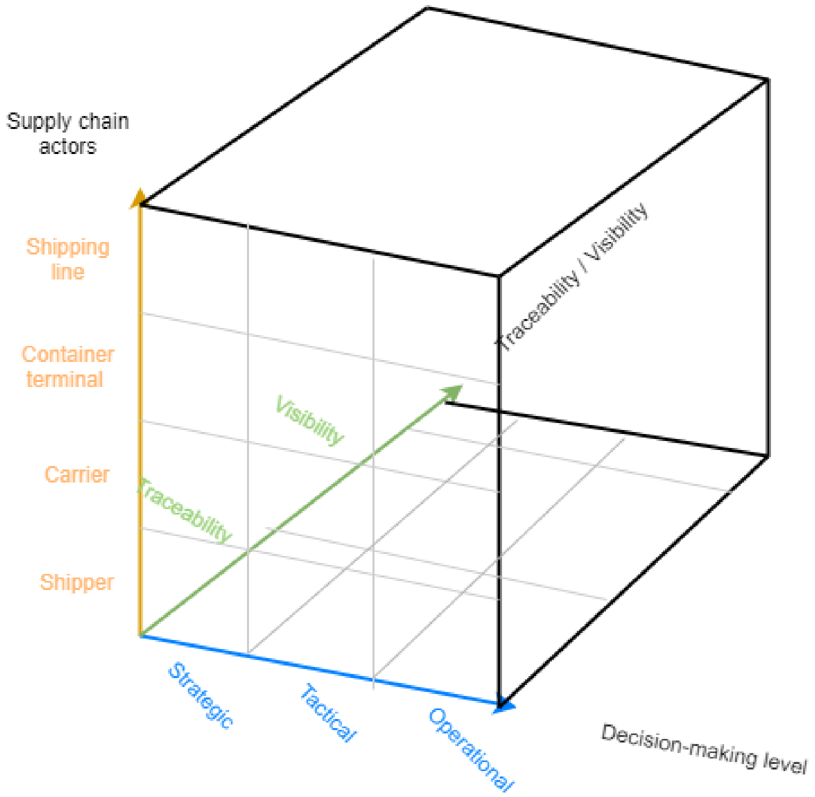

Figure 2. Risk management framework

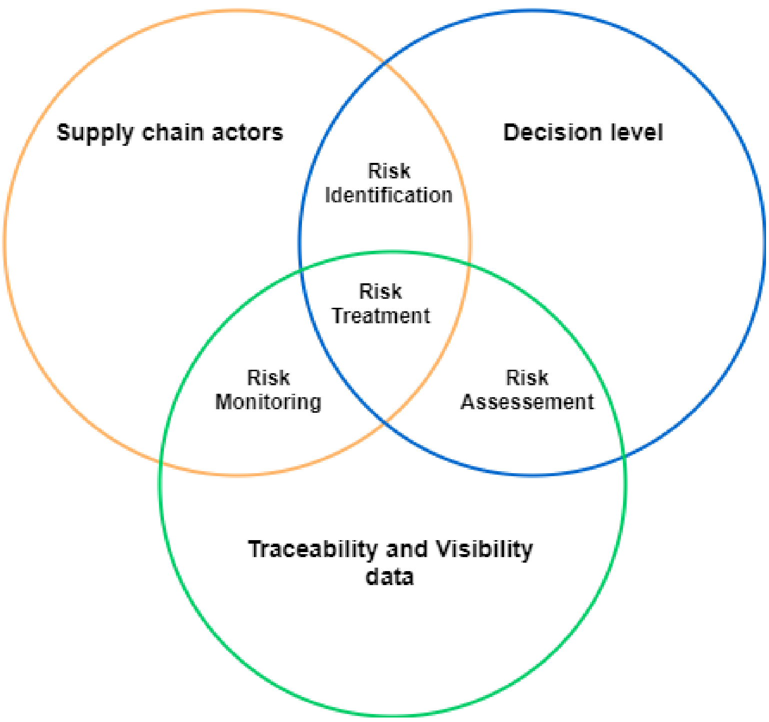

Figure 3. Relation between risk management process and risk management framework

Table 2. Risk Typology

Decision Level / Actor	Strategical		Tactical		Operational	
	Risk class	Risk events	Risk class	Risk events	Risk class	Risk events
Shipping line	Business	Fuel cost Storage cost	Organizational	Shipment planning	Supply	Congestion Vessel breakdown
	Environmental	Natural disaster				
	Demand	Uncertainty demand				
Carrier	Demand	Uncertainty demand	Organizational	Transport planning	Environmental	Uncertainty weather
	Business	Fuel cost Storage cost	Infrastructural	Lack of visibility Information transmission	Supply	Congestion Unexpected condition change
Container Terminal	Demand	Uncertainty demand	Organizational	Resource planning	Supply	Congestion Lack of worker Strike
	Environmental	Uncertainty weather				
Shipper	Supply	Piracy Deviation	X	X	Supply	Congestion Bad handling
	Environmental	Natural disaster			Infrastructural	Lack of visibility Lack of transport mode

3. Research Methodology

To achieve the objective of this work, a structured literature review on risk management in multimodal container transportation was achieved. This section aims to present the methodology used to make the review. The research methodology, presented in Figure 4, is composed of three mains steps that are used to capture important works done on multimodal container supply chain risk management and traceability:

- Articles collection
- Articles selection
- Articles analysis

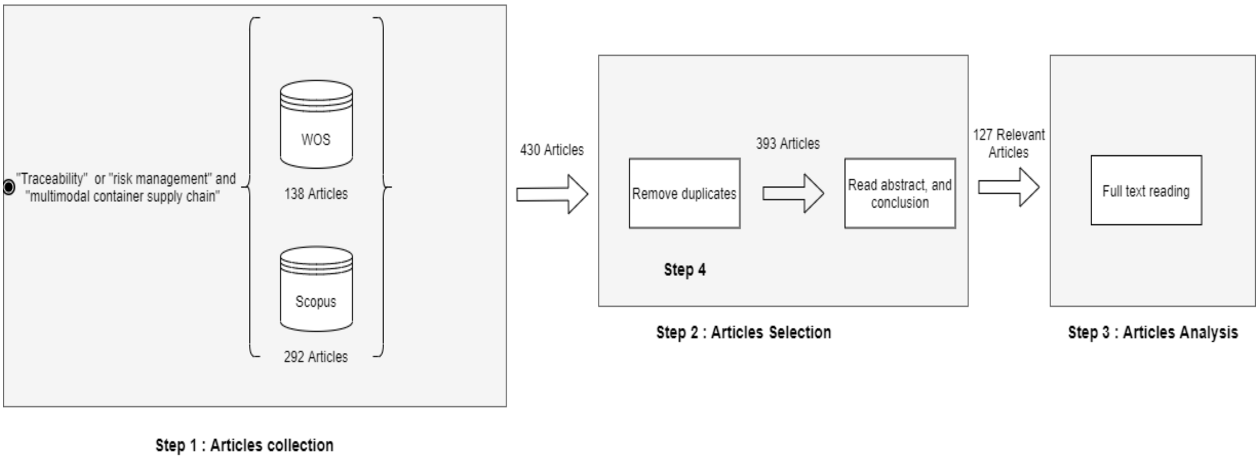

Figure 4. Research methodology

3.1. Articles collection

This section (step 1 in research methodology Figure 4) details the article collection process. Important keywords traceability, risk management, container and multimodal supply chain have been identified to shape the request to select the most relevant articles on the scientific databases. The request" (traceability OR risk management) AND multimodal container supply chain" was applied to gather articles of all fields on the two most relevant bibliographic databases (Web of science and Scopus) and request was refined with "maritime" as key word. This request was made October 28, 2021 and made it possible to recover 430 bibliographical references.

3.2. Articles selection

In this section, article selection (step 2 in research methodology Figure 4) process will be detailed. The selection step aimed to identify relevant papers matching with the research topic. An article was considered relevant when the topic addressed to it dealt with either the traceability of container or anomalies management in container multimodal transport. Firstly, duplicates articles were removed, in addition textbooks and book chapters and articles not written in English have been excluded. Hence only journal, conference articles written in English were selected. To be sure to only keep relevant articles for full text analysis, abstract, introduction and conclusion of all collected articles were read and lead to exclude works only dealing with air transport and those not dealing with container multimodal transportation. Since this paper aims to analyze methods for risk management in container multimodal supply chain, articles that do not propose methods or solutions to manage risk during container shipment were excluded as well. During the quick review (abstract, introduction and conclusion) of the articles we went back to interesting bibliographical references that we decided to add to our collection.

Finally, 127 articles were kept for a full reading after the selection phase.

3.3. Articles analysis

In this section a full text reading of each selected article has been made. The purpose of this article analysis step is to identify and gather solutions into the different features that are addressed to manage multimodal container transportation risk. The methods and data used to implement these solutions will also be analyzed and discussed. Container supply chain can be analyzed through several topics (route optimization, risk management, resilience...); in this article the analysis concerns the improvement of container transport performance through better risk management. The section 4 presents more detailed solutions proposed in literature in order to better manage container supply chain. These solutions have been grouped into 6 features:

1. Vessel path prediction
2. Vessel Estimated Time of Arrival prediction
3. Transportation monitoring
4. Carbon footprint reduction
5. Container terminal organization
6. Risk event monitoring

An analysis of the distribution of articles shows that there is a continuous growth in the number of articles focusing on traceability and multimodal container supply chain risk management published between 2000 and 2020 as seen in Figure 5. The figure shows an evolution of the number of articles published from 2011 with the intensive use of RFID technology to ensure traceability and monitoring in the transport of sensitive products.

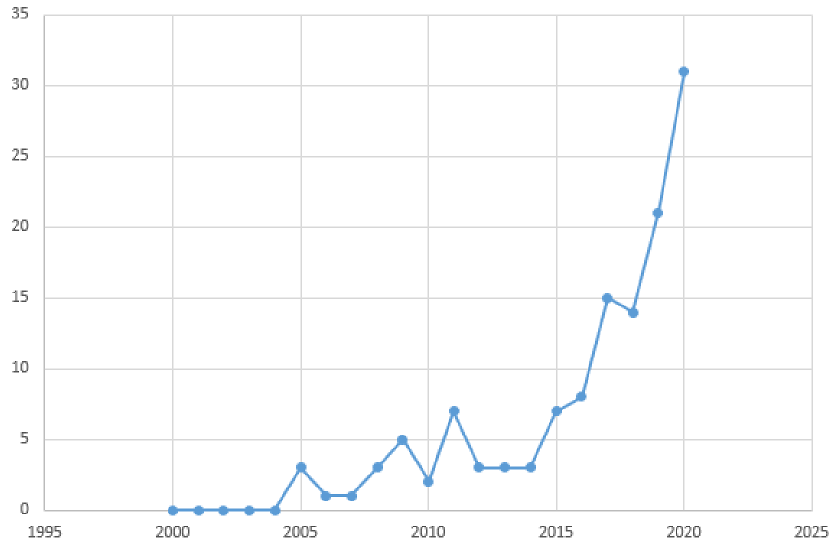

Figure 5. Article distribution

4. Review of features

In this section methods and solutions proposed in the literature for better multimodal container risk management have been reviewed and classified. There are several ways and different points of view to analyze the literature on supply chain risk management, but we are looking for literature in terms of features that can be integrated into a decision support system. All of the proposed methods, which aim to improve transportation performance and the security of transported products, provide features to stakeholders (shipping line, carrier, container terminal, shipper) involved in the transportation process. The Table 3 presents features addressed in the area of traceability and multimodal container supply chain risk management and the Figure 6 presents features distribution on collected papers. These following sections analyze the features addressed in the literature in terms of the methods and types of data used. Finally, an overview of industrial solutions that permit to ensure traceability and visibility of containers will be given.

Table 3. Features addressed in literature

Focus	Number	References
Vessel path prediction	13	(Pallotta, Vespe, and Bryan 2013; C. Zhang et al. 2020; Tu et al. 2020; Sahin and Soylu 2020; Alessandrini, Mazzarella, and Vespe 2019; Dorri, Kanhere, and Jurdak 2018; Shibasaki et al. 2017; Hansut, David, and Gasparik 2017; Fruth and Teuteberg 2017; Guo et al. 2015; Onut, Tuzkaya, and Torun 2011; Miller-Hooks et al. 2009)
Estimated time of arrival	6	(Alessandrini, Mazzarella, and Vespe 2019; Urciuoli 2018; Meijer 2017; Fruth and Teuteberg 2017; Parolas 2016; Qiao, Haghani, and Hamedi 2013)
Transportation monitoring	17	(Wide 2020; Chang et al. 2020; Aghalari, Nur, and Marufuzzaman 2020; Park et al. 2019; Giusti et al. 2019; Schoen et al. 2018; Mar-Ortiz, Gracia, and Castillo-García 2018; Slaczka, Pietrusewicz, and Marcinek 2017; Gallo et al. 2017; Papert, Rimpler, and Pflaum 2016; Bendriss and Benabdelhafid 2011; Hu et al. 2010; Cai, Hu, and Liu 2009; Mueller 2008; Longo and Ören 2008; Bollen, Riden, and Opara 2006)
Carbon footprint reduction	20	(Tao et Wu 2021; Liu and Wang 2021; Zhao et al. 2020; Pinakpani et al. 2020; X. Li, Kuang, and Hu 2020; Heinold and Meisel 2020; Cominelli et al. 2020; Vallejo-Pinto et al. 2019; W. Li, Hilmola, and Panova 2019; Hervas-Peralta et al. 2019; Baykasoğlu et al. 2019; Tsao and Linh 2018; Ma et al. 2018; D. Chen et al. 2017; Do et al. 2016; Cullinane, Tseng, and Wilmsmeier 2016a; Wong et al. 2015; Lack et al. 2011; Kontovas and Psaraftis 2011a; Matsukura et al. 2010)
Terminal organization	32	(Allen, McLeod, and Hutt s. d.; Fri et al. 2021; Z. Zhang et al. 2020; Wide 2020; Potgieter, Goedhals-Gerber, and Havenga 2020; He et al. 2020; Chargui et al. 2020a; Castelein, Geerlings, and Van Duin 2020; Andrews et al. 2020; Aghalari, Nur, and Marufuzzaman 2020; Park et al. 2019; He, Tan, and Zhang 2019; Cao and Lam 2019; Bhatti and Hanjra 2019; Baykasoğlu et al. 2019; Swieboda 2016; Mar-Ortiz, Gracia, and Castillo-García 2018; Expósito-Izquierdo, Melián-Batista, et Moreno-Vega 2018; C.-Y. Chen et al. 2018; Heilig and Voß 2017; Fotuhi and Huynh 2017; Agbo et al. 2017; Yang et al. 2016; Munuzuri et al. 2020; Folinas et al. 2015; Bentaleb, Mabrouki, and Semma 2015; Alyami et al. 2014; Coppolino et al. 2011; Mueller 2008; Mennis et al. 2008; Longo, Mirabelli, and Tremori 2009; Longo, Mirabelli, and Bruzzone 2005)
Risk events monitoring	41	(Hsu, Huang, and Wu, s. d.; Gunes, Kayisoglu, and Bolat 2021; Wide 2020; Tadic et al. 2020; Potgieter, Goedhals-Gerber, and Havenga 2020; Nguyen 2020; Jiang and Lu 2020; He et al. 2020; Filina-Dawidowicz, Możdrzeń, and Stankiewicz 2020; Y. Fan, Behdani, and Bloemhof-Ruwaard 2020; Chang et al. 2020; Yan, He, and Trappey 2019; J. Vilko, Ritala, and Hallikas 2019; Tseng et al. 2019; Shen et al. 2019; Šakalys et al. 2019; Mahmood et al. 2019; Hossain et al. 2019; Alessandrini, Mazzarella, and Vespe 2019; Nguyen and Wang 2018; Mar-Ortiz, Gracia, and Castillo-García 2018; C.-Y. Chen et al. 2018; Slaczka, Pietrusewicz, and Marcinek 2017; Lam, Liu, and Gou 2017; Gallo et al. 2017; Emenike, Eyk, and Hoffman 2016; Harris, Wang, and Wang 2015; Güller et al. 2015; Pallotta, Vespe, and Bryan 2013; J. P. P. Vilko and Hallikas 2012; L. Fan, Wilson, and Dahl 2012; L. Fan and Wilson 2012; Pant et al. 2011; Lättilä and Saranen 2011; Hu et al. 2010; Amador, Emond, and Nunes 2009; Mueller 2008; Mennis et al. 2008; Bukkapatnam and Komanduri 2007; T. C. Chen 2005)

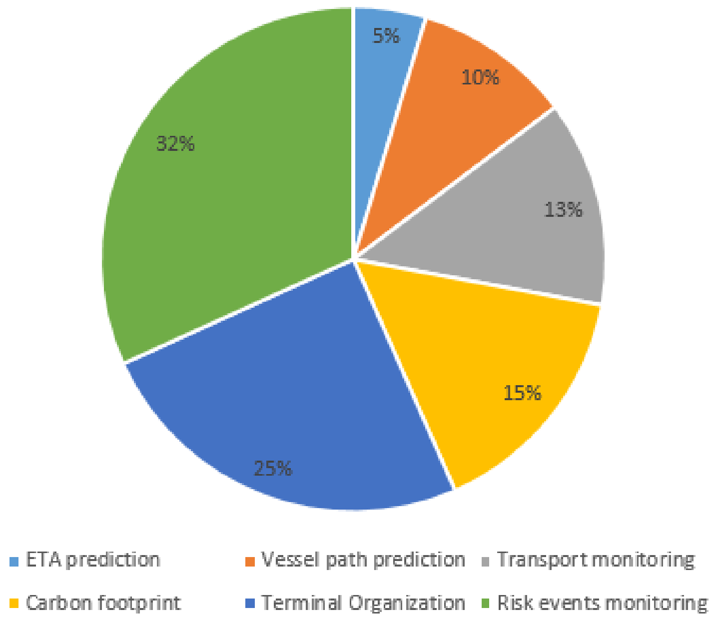

Figure 6. Features distribution

4.1. Features for improving multimodal container supply chain risk management

The traceability and visibility of the supply chain have enabled researchers to investigate solutions and methods to improve the performance of containerized transport. For example, end-to-end traceability and visibility of the supply chain makes it possible to optimize time spent in port by vessel for container load and unload.

These features and methods used to set them up will be discussed in sections below.

4.1.1. Vessel path prediction

Unlike road and rail traffic there is not topography or database representing the network on which sea vessels move (Urciuoli 2018). A vessel path can be assimilated as a graph where the nodes represent the ports and the links are the possible routes between a port A and a port F (Figure 7). Fortunately, in container maritime shipment, the majority of shipping lines use regular routes. This allow an identification of the routes thanks to the traceability data. It is possible to find all vessel passage points from its port of departure to the port of arrival. Vessel route prediction frameworks use vessel historical AIS data (traceability) to discover vessel behavior and then vessel location (visibility) is used to detect optimal route between vessel origin and destination. The famous framework use to predict vessel path is the Traffic Model and Knowledge Discovery proposed by (Parolas 2016). This framework automatically learns a statistical model from AIS data in order to extract routes. Vessel route prediction is a necessary condition for the implementation an ETA prediction feature and it also permit to improve real-time risk assessment during container shipment. Indeed, the majority of the authors who have proposed methods for the prediction of the ETA of vessel in the port proposed or used methods to predict or know the vessels path. In addition, knowing vessel path makes it easier to predict hazardous events that can occur during container transportation. (C. Zhang et al., 2020) write that" the research on predicting global vessel destinations would be of great value for the industry to make timely and efficient decisions and ensure a safe and efficient maritime traffic environment". For example, by knowing a vessel path, a shipper can decide for a higher insurance policy in order to share thief of damage risk if the vessel passes by a congested (Dorri, Kanhere, and Jurdak 2018) route or one that is highly frequented by pirates. Many authors (Tu et al. 2020; S. Wattanakul et al. 2019; Sahin et Soylu 2020) in multimodal supply chain management proposed frameworks and methods to predict vessel paths based on vessel tracking data, fuzzy data processing in order to optimize transportation cost and time. For example, (Tu et al. 2020) test different machine learning approaches in order to find a vessel path with better accuracy. The authors in (Alessandrini, Mazzarella, and Vespe 2019) proposed a path finding algorithm in order to find optimal route between two geographical locations while minimizing travel cost. The Table 4 gathers these methods.

Table 4. Methods for Vessel route prediction

Method used	Data	Accuracy	Reference
Optimization algorithm	AIS	Depending of Data quality	(Alessandrini, Mazzarella, and Vespe 2019; Pallotta, Vespe, and Bryan 2013; Sahin v Soylu 2020; Onut, Tuzkaya, and Torun 2011)
K-nearest neighbor regression	AIS	Depending of Data quality	(Meijer 2017; Tu et al. 2020)
Neural Network	AIS	0.6	(Meijer 2017; Z. Zhang et al. 2020)
Support Vector Machines	AIS and weather	Depending of Data quality	(Meijer 2017; Parolas 2016)
Random Forest	AIS	0.81	(C. Zhang et al. 2020)
Simulation	N/A	N/A	(Dorri, Kanhere, and Jurdak 2018; Shibasaki et al. 2017)

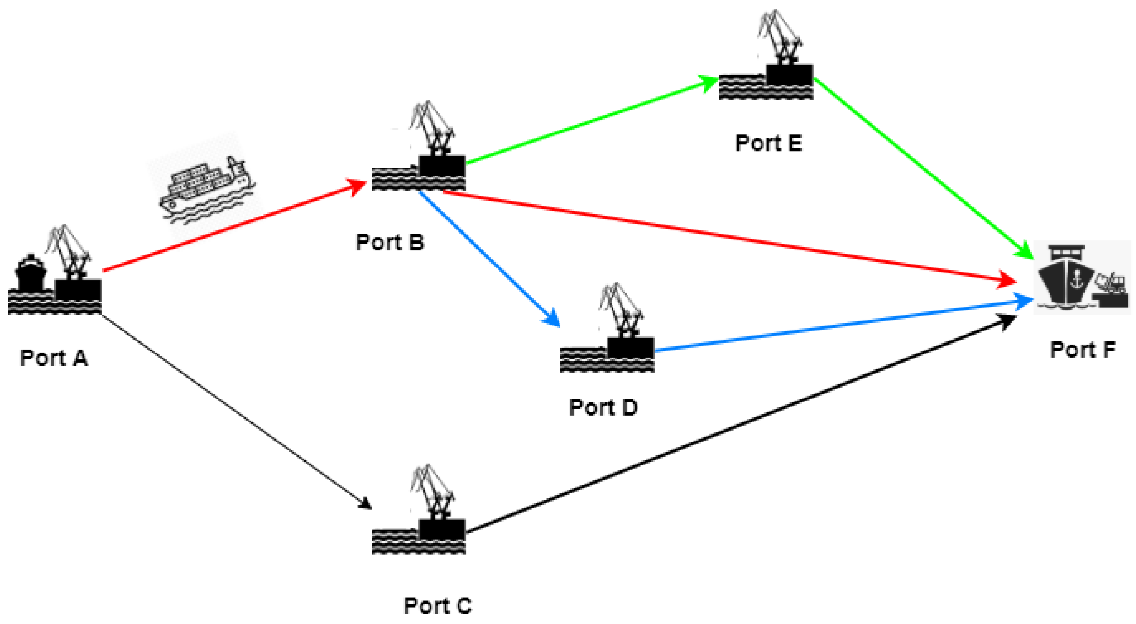

Figure 7. Vessel Path

4.1.2. Vessel Estimated time of arrival prediction

The prediction of the estimated time of arrival (ETA) of a vessel is a subject which is of great interest to the majority of actors in the international transport chain. A better estimate of the arrival time allows the carrier and the shipping line to guarantee the delivery time of containers and to provide a high level of service to their customers. It allows the port authorities to improve the organization in the port terminals and thus to minimize the processing times at the port and the costs associated therewith. In addition, a better estimation of the ETA allows the customs authority, the freight forwarder and the customers, to better organize themselves to receive the containers. The stakes are high around ETA's prediction. However, the ETA communicated by shipping lines during international shipment is estimated by the vessel's captain and entered manually into Auto-Identification System (AIS). This ETA is not always reliable because of potential human errors (entry errors, omissions ...) and it does not consider hazardous events. However, many processing industries work just in time in order to keep storage costs down. In order to allow the containerized transportation to work just in time, authors in the literature have proposed methods that are mostly time-based on traceability data and artificial intelligence for a better estimated vessel ETA.

ETA prediction consists in estimating the time of arrival of vessel at the port of arrival based on the vessel path, its speed, the distance remaining to be covered and other parameter such as weather. Several works have been identified in this systematic literature review. For example, (Alessandrini, Mazzarella, and Vespe 2019) used vessel traceability and visibility data (AIS data and Long Range Identification and Tracking) to propose an optimization algorithm to find vessel path and speed in order to predict vessel ETA. These authors used vessel traceability data (historical AIS data) vessels behavior and motion patterns. Then, they used optimization algorithm to find vessel path based on vessel extracted behavior, vessel location and vessel final destination while minimizing a cost feature. Vessel location is determined thanks to the visibility data (real-time AIS data). To calculate ETA, these authors used vessel speed and distance to the next point in the vessel path. The result of this proposed method depends on estimation on vessel speed and the performance of optimization algorithm to find vessel path. The authors in (Meijer 2017; Parolas 2016) discuss different techniques of AI that can be used in ETA prediction. These AI techniques take vessel traceability and visibility such as AIS data, navigation environment condition and vessel path as input. The authors in (Meijer 2017) test different AI techniques (Regression, Neural Network, support vector machines ...) for ETA prediction and choose K-nearest neighbors regression because it was easy to use and understand in their use cases. Other authors (C. Zhang et al. 2020) proposed an ETA prediction model based on traceability data (141 million AIS records data) and random forest algorithm. The authors in (Urciuoli 2018) proposed a framework a for better ETA prediction. Six modules are usually developed in ETA prediction framework:

- Navigation Path identification
- Collect historical information: Traceability data
- Collect Real-time information: Visibility data i.e. vessel location, vessel speed, wind speed and direction.
- Merge with historical information: Correlate the information collected on the risks, the meteorological conditions with the performance of the vessel thanks to the visibility data.
- Delay times estimation: Estimate the delay for both routes and port waiting time." The analyst initially computes the risk-free travelling times of vessels along the route, thereby he/she proceeds by combining the risk-based travelling time estimations (Urciuoli 2018).
- Compute ETA

The table 5 gathers methods proposed in literature to predict ETA.

Table 5. Methods for ETA prediction

Method	Data	Accuracy	References
Historical Average Model	Traffic data	Fail to deal with variation	(Qiao, Haghani, and Hamedi 2013)
Time-series	Traffic data	Fail to deal with variation	(Qiao, Haghani, and Hamedi 2013)
Optimization algorithm	AIS	Depending of vessel speed prediction	(Alessandrini, Mazzarella, and Vespe 2019)
Neural networks	AIS and Weather	Depending of the number of neuron	(Meijer 2017)
K-nearest neighbor regression	AIS	Depend on the route	(Meijer 2017)
Decision Trees	AIS	NA	(Meijer 2017; Parolas 2016)
Random Forest	AIS	0.81	(C. Zhang et al. 2020)
Support Vector Machines	AIS and Weather	Depending of the location	(Meijer 2017; Parolas 2016)

4.1.3. Container transportation monitoring

Multimodal container transportation is a complex process; indeed, container transportation can involve more than twenty stakeholders. This complexity creates a loss of visibility and information for shipper, buyer and for carrier during maritime shipment. In addition, containerized transportation is often found subject to random events which cause a drop in the performance of the entire supply chain. Rail, sea and road transportations are affected by congestion, bad weather conditions, security and strikes at seaports (Urciuoli 2018). These random events are the cause of severe delays and quality loss for transported products. In order to permit supply chain managers to be more reactive, researchers design monitoring system based on different technologies and methods which permit to give end to end visibility. Monitoring systems are designed by using different types of sensors (temperature, pressure, light...) to capture container internal and external environment variation and different types of technologies to collect data. For example, Amador et al (Amador, Emond, et Nunes 2009) studied the use of RFID in temperature monitoring in order to increase temperature monitoring performance in pineapple supply chain. (Bukkapatnam and Komanduri 2007) used vibration sensor to monitoring operating conditions of a container during transshipment process. The development of technology makes it possible to build a smart container based on internet of thing. The Table 6 summarizes sensors use to capture container environment variation and Table 7 summarizes technologies use to gather data during shipments.

Table 6. Sensors use for transport monitoring

Sensors	Data	Reference
Temperature	Temperature variation	(Alessandrini, Mazzarella, and Vespe 2019; Emenike, Eyk, and Hoffman 2016; Pallotta, Vespe, and Bryan 2013; Sahin and Soylu 2020)
RFID tags	Temperature variation	(Amador, Emond, and Nunes 2009; T. C. Chen 2005; Emenike, Eyk, and Hoffman 2016)
Accelerometer	Vibration	(Bukkapatnam and Komanduri 2007)
GPS	Location	(Bukkapatnam and Komanduri 2007)

Table 7. Technologies for data transmission

Technologies	Advantages	Disadvantages	References
GSM	Highly developed telephony	Interdependent to telecoms networks	(Alessandrini, Mazzarella, and Vespe 2019; Emenike, Eyk, and Hoffman 2016; Pallotta, Vespe, and Bryan 2013; Sahin and Soylu 2020)
RFID	Passive tag	Dedicated infrastructure	(Amador, Emond, and Nunes 2009; T. C. Chen 2005; Emenike, Eyk, and Hoffman 2016)
Wi-Fi	Good precision	Coverage area to be established	(Bukkapatnam and Komanduri 2007)
Satellite	Good precision	High price	(Bukkapatnam and Komanduri 2007)
Sigfox	Good coverage	Low adaptability	(Bukkapatnam and Komanduri 2007)

4.1.4. Carbon footprint estimate and reduction

Pollution has significant effects on health and the environment and transportation industry is largely responsible for this pollution, indeed container vessel is the top fuel-consuming categories of ships and hence air polluters (Kontovas et Psaraftis 2011a) because they have a large shipping tonnage and their voyage speed is relatively high compared to other ship types (Matsukura et al. 2010). Many authors have been interested in estimating the Co_2 produced by the ship during container transportation. Two approach are often time used to estimate Co_2 emission during shipment (Tao and Wu 2021): (1) energy based method and (2) activity based method.

1. In energy based-method, Co_2 emission are calculating" by summing the multiplied energy consumption by energy type and the energy-specific Co_2emission factors, where the energy specific Co_2emission are provided par IMO".
2. Activity-based method calculates Co_2emission" by summing the multiplied freight turnover per energy type, the energy consumption by energy type per turnover, and the energy specific Co_2emission factor".

For example, (Cullinane, Tseng, and Wilmsmeier 2016a; Do et al. 2016; Cominelli et al. 2020; Wong et al. 2015; Zhao et al. 2020; Pinakpani et al. 2020) proposed a mathematical model to estimate vessel carbon footprint impact based on the following criteria: Departure and destination port to calculate the distance to be covered by vessel, vessel speed and vessel waiting times on hub ports. Some group of authors also investigate on the reduction on carbon footprint during multimodal transportation. The authors in (Kontovas and Psaraftis 2011b; Lack et al. 2011) investigate on the impact on Co_2 of vessel speed reduction and fuel quality. The authors in (Heinold and Meisel 2020; Matsukura et al. 2010) design an optimization model for selecting the best road that minimizing vessel emission during shipment. (Do et al. 2016) proposed a model based on discrete event simulation and genetic algorithm in order to minimize emission (Co_2 and Nox) in container terminal. Estimation and reduction of emissions along the container multimodal transportation is one the subject that literature of supply chain risk management address in order to build sustainable transportation system (Beškovnik and Golnar 2020a). Indeed, a better emission estimation allow container supply chain actors to consolidate their carbon impact and to determine which method they can choose to reduce their carbon footprint. Among the methods proposed to reduce the carbon footprint of vessels, we commonly find the reduction of vessel speed (Kontovas and Psaraftis 2011b; Do et al. 2016), simulation to choose routes that consume less energy (Beškovnik and Golnar 2020b). The Table 8 summarizes the methods proposed in the literature to estimate and reduce the carbon footprint during shipment.

Table 8. Methods for carbon footprint reduction

Method	Focus	Reference
Mathematical model	Co_2 estimation	(Beskovnik and Golnar 2020 ; Zhao et al. 2020 ; Ma et al. 2018 ; Vallejo-Pinto et al. 2019)
Genetic algorithm	Co_2 reduction	(Do et al. 2016)
Simulation	Co_2 estimation	(Beskovnik and Golnar 2020; Liu and Wang 2021)
Reduce service time	Co_2 reduction	(Kontovas and Psaraftis 2011b)
Support Vector Machin	Co_2 reduction	(Kontovas and Psaraftis 2011a)
Analytic Hierarchy Process (AHP)	Co_2 reduction	(Hervas-Peralta et al. 2019)

4.1.5. Container terminal operation optimization

Port terminals are strategic points for multimodal container transportation. Indeed, the performance in transport is directly dependent on the efficiency of the operations carried out on the terminals. Optimization of operations at the terminals makes it possible to reduce the waiting time for vessels during the loading and unloading of containers. It's also permit to be more precise on the estimation of ETA and thus increase the performance of the entire transportation chain. End to end supply chain visibility allow to improve organization in container terminal. The author in (Munuzuri et al. 2020) highlight three operational benefit that traceability and visibility data can bring to container terminal:

- A traceability system represents a competitive advantage for the terminal. This will allow it to gain additional traffic compared to its competitors.
- The traceability system also reduces costs. Indeed" train management and guidance, navigation planning, crane and workforce scheduling or customer management are essential tasks that will see a reduction in the amount of resources that need to be devoted to them" (Muñuzuri et al. 2016).
- " Finally, the third source of positive effects for the terminal is the increase inefficiency resulting from the implementation and appropriate use of management the system, particularly in all the aspects related to the sequencing of vessels (due to an improved navigation system) and trains (due to better train scheduling, internal guidance and incidence management)"(Muñuzuri et al. 2016).

Some authors (Chargui et al. 2020a; Hervas-Peralta et al. 2019) have been proposed methods for container terminal organization in order to reduce congestion and carbon footprint during container multimodal transportation (Hervas-Peralta et al. 2019). For example, (Chargui et al. 2020a) proposed a predictive model for quay crane rate in maritime logistics operations based on artificial neural network in order to improve the performance of transportation supply chain. The Table 9 summarizes the methods proposed in the literature to optimize organization in container terminal.

Table 9. Methods for container terminal operations optimization

Methods	Focus	Reference
Neural Network	Operation optimization	(Chargui et al. 2020a; Expósito-Izquierdo, Melián-Batista, and Moreno-Vega 2018)
AHP	Terminal organization	(Hervas-Peralta et al. 2019; Sahin and Soylu 2020; Bentaleb, Mabrouki, and Semma 2015; Alyami et al. 2014; Bhatti and Hanjra 2019)
Conceptual model	Economic efficiency	(Allen, McLeod, and Hutt s. d.; Fri et al. 2021; Park et al. 2019)
Optimization algorithm	Operation optimization	(Aghalari, Nur, and Marufuzzaman 2020; C.-Y. Chen et al. 2018; Fotuhi et Huynh 2017; Mennis et al. 2008)
Simulation	Risk mitigation	(Cao and Lam 2019; Longo, Mirabelli, and Tremori 2009; Longo, Mirabelli, and Bruzzone 2005)

4.1.6. Risk events monitoring and detection

Multimodal container transportation is exposed to various hazardous events that affect the supply chain of all the stakeholders involved in the transportation process. Container security and transported products quality depend on the right conditions of packaging, a secure energy supply for sensitive cargoes, and adequate handling of the container at various transfer points (Chargui et al. 2020b). Cargo lost occur due to technical failure during container transportation and organization error caused severe quality and financial impact on supply chain. A review of the literature shows that many authors have been interested in how to ensure the quality of the transported products and the safety of the containers especially in the transportation of sensitive products where there is a need for continuous transport condition control cargoes (Castelein, Geerlings, and Van Duin 2020) proposed methods and design system based on traceability and visibility data in order to monitor and detect. The monitoring phase in the risk management process consists of monitoring and ensuring that the risk remains at a manageable level. The methods used in risk event monitoring during container transportation are the same used for transportation monitoring. Risk event monitoring system are design by added sensors to container in order to detect container environment variation during shipment. If the variation exceeds the tolerance threshold, an alert is generated to warn the supply chain manager. Monitoring and detection system are well documented for sensitive good transportation. Hasan et al (Heinold and Meisel 2020) proposed solution using smart container to monitor container inside environment and smart contract to track and manage automate payments." Smart containers equipped with Internet of Things (IoT) sensors that can be used to track and monitor predefined shipping conditions related to temperature, geographical location, humidity, pressure, light exposure, sudden fall, broken seal" (Heinold et Meisel 2020) and smart contract use Blockchain technology.

4.2. Industrial solution for multimodal supply chain risk management

The containerized transport sector has taken advantage of the development and advances in technology and data processing techniques to improve transport performance and offer more visibility to the various stakeholders. The proposed solutions are based on the Internet of Things (IoT) and web service technologies to ensure tracking and safety of the transported products. There are mainly two types of solutions: solution proposed by transport service provider and solution proposed by logistic service provider.

4.2.1. Solution proposed by transport service provider

Transport service provider (TSP) can be defined as a company that takes care of transporting the container from point A to point B e.g. shipping line or inland carrier are TSP. Thanks to Electronic Data Interchange (EDI) and the Automatic Identification System (AIS), the shipping line are able to calculate with some accuracy the exact location of a container. The EDI permits to improve communication between stakeholders in maritime area by giving real-time data transfer standard. This allows to create a web-EDI that gives the container location by using container identification number. Inland carrier use Transportation management system (TMS) to improve transportation performance. A Transport Management System is a tool that help to manage transport. The TMS mainly addresses the needs of traceability of deliveries and optimization of transport (schematics and assignment of carriers) and makes it possible to improve the organization of the transport. These improvements translate into a reduction in the transport budget (Schoen et al. 2018). The main features of TMS are:

- Optimization engine
- Real-time tracking
- Carrier contracts management
- Reports and Business Intelligence

4.2.2. Solution proposed by logistic service provider

The logistic service provider (LSP) can be defined as a company which organizes and manages containers transportation for shipper. LSP selects the carriers and the shipping lines for shipper while optimizing transportation cost. In order to improve their service level agreement and guarantee the safety of the containers transported, the LSPs offer, in collaboration with tracking companies, solutions for the real-time monitoring of shipments. These solutions are composed either of a web platform which aggregates AIS data to track the vessel on which the container is located, or of a cyber-physical system composed of a smart container and a web platform which allows to visualize in near real time the position of the container and follow the variation of the internal environment of the containers. The concept of smart container has been put in place to overcome the traceability problem encountered in the container transportation. Indeed, the knowledge of the paths and the real-time position of the container allows to protect against theft, loss and other risk during shipment. Building a smart container means using technological and scientific advances to ensure traceability and safety of container.

5. Discussion

These sections aim to answer to the research questions based on the analysis of section 4.

5.1. Reviews Critical analysis

Multimodal supply chain risk management has been the subject of extensive research over the past 20 years. This research aims to improve transportation performance by proposing methods can implement as a features in decision system support. The way we analyze solutions proposed in the literature to ensure optimality and safety in container transportation allow us to classify the set of works following 6 main features. Use of Internet of Things offer better traceability and visibility in port operation and during multi-modal container transportation. Research also reveal the existence of lot of work trying to optimize supply chain risk management. These works are based on AIS data, artificial intelligence (Yan, He, and Trappey 2019), big data (Fruth and Teuteberg 2017), simulation (Hilmola and Lättilä 2013) and other mixed techniques. However just few of these methods integrate real-time data in their process (Güller et al. 2015; Siraprapa Wattanakul et al. 2018). Thanks to various technological advances, TSP and LSP propose commercial solutions ensuring container tracking. These solutions help to monitor containers environment and send reactive events alerts during shipment. But these solutions find their limits in terms of doing analytical processing of data and prediction in transport condition.

5.1.1. Features Analysis

5.1.1.1. Vessel path and ETA prediction feature analysis

Vessel route path and ETA prediction are well documented in literature. The sections 4.1.1 and 4.1.2 present works based on different artificial intelligence techniques in order to improve risk management during shipment. However, these techniques are essentially based on vessel traceability data. Therefore, these methods are only interested in the prediction of ETA and the route plan from port to port, door-to-door ETA estimate is not provided. In addition, other factors like weather and social events can impacts supply chain network need to be considered in vessel path and ETA prediction.

5.1.1.2. Container transportation and risk events monitoring feature analysis

Container transport monitoring system is the most documented subject in container multimodal supply chain risk management. The articles falling in this center of interest represent more than half of the articles studied. Most of solutions proposed in literature to monitoring risk event during container transit are based on used of smart devices (sensors) in order to capture inside container environment variations. Then this variation is compare to normal state in order to generate alerts. These monitoring system are mostly design for foods transportation, the Figure 8 give products supply chain where these systems are used. These monitoring solutions find their limit in the fact that during maritime transport the transmission of data is interrupted.

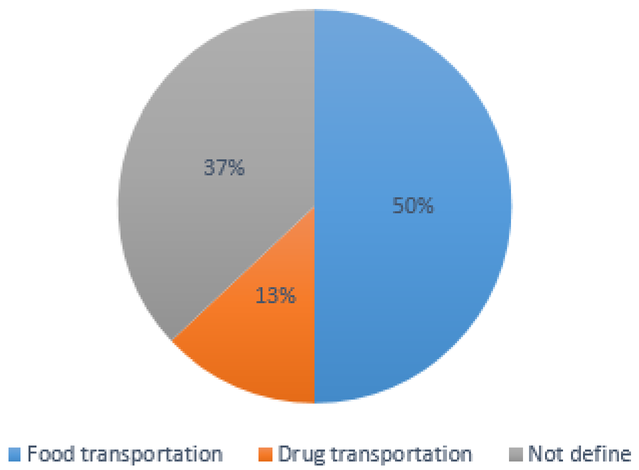

Figure 8. Monitoring of products supply chain

5.1.1.3. Container terminal operation and carbon footprint estimation and reduction feature analysis

Many authors have taken an interest in the optimization of container terminals and container carbon footprint estimation and reduction. Methods used for container terminal operation optimization aims to avoid congestion, long waiting time in container terminal.

A container operation optimization also permits to reduce Co_2 emission at port. Carbon footprint estimation and reduction aims to calculate Co_2 emission of transport (road, rail and vessel) mode during multimodal transportation in order to build a green sustainable container supply chain by reducing emission. Literature analysis allows us to identify that all the authors have focused on estimating and / or reducing carbon footprint of container transport modes while abandoning container's carbon footprint itself. Only two articles have proposed ways to calculate multimodal container carbon footprint, but no case study has been done on a single container transportation. The Figure 9 shows the distribution of Co_2 emission estimation works according to the transportation mode, we note that the majority of work relates to the Co_2 emissions estimation at containers terminal and on sea transportation.

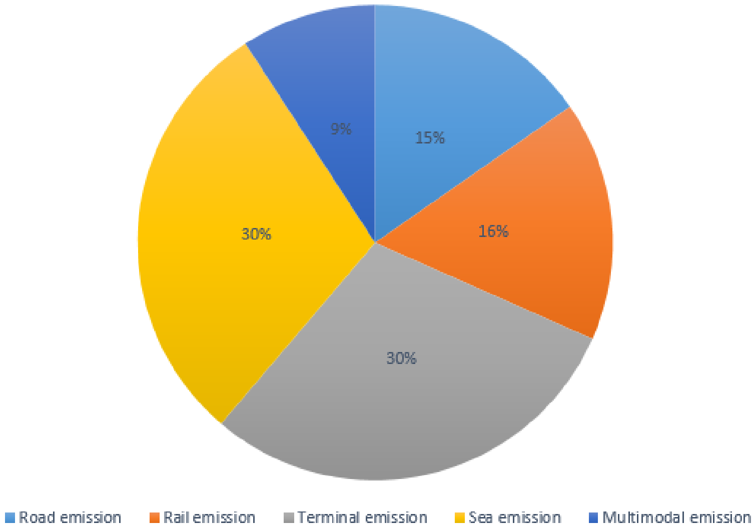

Figure 9. Distribution of carbon footprint estimation

5.1.2. Data

The various techniques proposed by the authors to improve the performance of container transportation are essentially based on transport traceability data (AIS data and historical data). For example, some authors used Automatic Information System (AIS) data to predict vessel path and estimate vessel ETA (Bollen, Riden, and Opara 2006; Parolas 2016). Indeed, since 2005 the majority of container ships are obliged to have Automatic Information System installed, which is an excellent source of information for vessel visibility. AIS messages communicate statistic information (IMO, vessel type, antenna position…) and dynamic information (vessel position, time, vessel speed...) to other vessels, inland stations and also to satellites (Meijer 2017). Information provided by AIS is essential and widely used for monitoring the external environment of vessel during multimodal container transportation. The Table 10 gives references which used AIS data to propose features in order to improve risk management during shipment. However, for monitoring internal environment of the container for sensitive transport, AIS data is not very effective. To overcome this problem, other authors have proposed systems using sensors attached to the containers to retrieve information on container inside condition variations. For example, in order to improve cold chain management, the authors in (Amador, Emond, and Nunes 2009; Castelein, Geerlings, and Van Duin 2020; Emenike, Eyk, and Hoffman 2016) used temperature sensor to monitor temperature variations inside the container during foods shipment and alert in case of abnormal variation. The authors in (Bukkapatnam and Komanduri 2007) used accelerometer to capture vibration during container transportation in order to detect mishandling during containers transportation.

It is important to note that most of the features proposed for improving the performance of containerized transport (ETA prediction, vessel path prediction) are based on AIS data, which means that results of the different algorithms are highly dependent on quality of input AIS data. AIS messages contain a lot of variables and the ETA prediction depends on the variables considered. In order to have better prediction of ETA or vessel path AIS data need to be improve before using them. For example, (Meijer 2017) analyze AIS messages in order to choose best variables in order to improve ETA prediction. The authors in (Munuzuri et al. 2020) conclude that weather data does not influence ETA prediction. Few of studies (Alessandrini, Mazzarella, and Vespe 2019; Meijer 2017; Munuzuri et al. 2020) name the variables considered in their methods. The Table 11 gives authors references who have proposed solutions to ensure inside environment traceability and visibility of container during shipment.

Tables 10. Studies using AIS data

Focus	References
Vessel path prediction	(Alessandrini, Mazzarella, and Vespe 2019; Pallotta, Vespe, and Bryan 2013; Tu et al. 2020)
Vessel destination prediction	(C. Zhang et al. 2020)
ETA prediction	(Alessandrini, Mazzarella, and Vespe 2019; Meijer 2017; Pallotta, Vespe, and Bryan 2013; Parolas 2016; Urciuoli 2018)
Co_2 emission reduction	(D. Chen et al. 2017; Cullinane, Tseng, and Wilmsmeier 2016b; Lack et al. 2011; Lim et al. 2018)

Tables 11. Studies using IoT data

Focus	References
Traceability	(Siraprapa Wattanakul et al. 2018; Chang et al. 2020; T. C. Chen 2005; Lam, Liu, and Gou 2017; Mueller 2008; Potgieter, Goedhals-Gerber, and Havenga 2020; Slaczka, Pietrusewicz, and Marcinek 2017; Hu et al. 2010)
Visibility	(Mahmood et al. 2019; T. C. Chen 2005; Bukkapatnam and Komanduri 2007; Castelein, Geerlings, and Van Duin 2020; Guo et al. 2015; Munuzuri et al. 2020; Papert, Rimpler, and Pflaum 2016)
Scheduling	(Guo et al. 2015; Emenike, Eyk, et Hoffman 2016)

5.2. Recommendation and suggestion

Complexity of multimodal container transport process and large number of actors involved in this process increase disruption and lack of visibility on container supply chain. However, traceability and visibility are the bases of risk management in multimodal container transport. Container supply chain risk management literature analysis shows that studies focused on proposing methods and framework (AI, mathematical model) that integrate vessel traceability and visibility data (AIS) in order to better manage risk. Another group of studies focused on designing systems that integrate sensors into container, it's a concept of smart container. These containers make it possible to capture traceability and near real-time visibility data during shipment by monitoring the internal environment of the containers and by tracing the exact location of the container. However, we didn't find any studies using jointly vessel's traceability/visibility data and smart container data at the same time to ensure a complete visibility on the container transportation conditions. The review also shows that thanks to scholar research and technological advance, industrial solutions ensuring container tracking have been proposed. These solutions help to monitor containers environment and send reactive alerts on the events during its transit. But these solutions find their limits when it comes to apprehend analytically risk impact on the supply chain and its prediction. SCRM analysis shows that new Predictable Risk Management Approach by using AIS data and smart container data in multimodal container transportation is necessary. Indeed, the author in [18] argue that real-time data integration will permit to be more proactive in decision-making process. On this basis, (Güller et al. 2015) proposed a simulation-based decision support system for the real-time management of disruptions and mitigation of risks in supply chains, in the same way (Zou et al. 2016) introduce a new method, which uses field programmable gate array (FPGA) to design embedded device in order to reduce risks which caused by time delay in supply chain network (SCN) and (Siraprapa Wattanakul et al. 2018) proposed a framework using historical and real-time sensor data to improve reactivity and pro-activity in container shipment. However, none of these proposed methods or framework take vessel AIS data into account, this show that the potential of use traceability and visibility data to realizing proactive and predictive SCRM hasn't completely explore by researchers. Indeed, authors in (Yan, He, and Trappey 2019) came to the same conclusion when they carried out a review on risk-aware supply chain intelligence and argued by research can leverage on the development of artificial intelligence and other intelligent techniques to achieve better results.

To overcome the limitation on container supply chain risk management, it will therefore be relevant to focus on a AI techniques based on traceability and visibility data for automating decision making in supply chain risk management. Learning and prediction algorithm will be use in future works for:

- Detecting risk
- Evaluate their occurrence and impact
- Choosing best response strategy

6. Conclusion

6.1. Review limitation

This paper has some limitations like other scientific papers. All relevant articles may not have considered in this review. Indeed, only articles published between 2000 and 2020 have been selected, in addition there is a lack of alternative concept words in keys works choice, e.g. hazardous events, disruption or uncertainties are alternative concept names for risk.

Then articles classification in different features requires a particularly analysis, author misconception cannot be totally excluded. Despite these limitations, this article presents a strong analysis of literature on multimodal container supply chain risk management and give some recommendation for future works.

6.2. Closing and future works

Supply chain risk management has been widely documented over the past twenty years. The objective of this study was to propose a state of the art of features and solutions (scientific and industrial) in the field of multimodal container supply chain risk management. A structured literature review was performed on 127 articles published between 2000 and 2020. Articles analysis show that many authors based on shipment traceability and visibility data proposed methods in order to better manage risk events encountered on container supply chain. These methods used various techniques (artificial intelligence, simulation, formal safety assessment...), different data parameters and can be brought under the scope of 6 main features. This review also analyzes data (AIS data and container inside variation data) used in supply chain risk management.

This article highlights a lack of integration of traceability and visibility data on container supply chain risk management. Indeed, there is a real need to integrate simultaneously vessel and container traceability and visibility data into multimodal container supply chain management in order to have end to end visibility on supply chain and to be more reactive and proactive in decision making process. In fact, container visibility data provides container inside environment variations. These data thank to analytical analysis and IA model will permit to detect and evaluate risks impact on transported products (temperature variation, door opening...). Vessel traceability data (AIS data) allows to predict with more accuracy vessel ETA and vessel path. These two types of data are complementary for predictive risk management. Predictive risk management will help supply chain stakeholders to be more reactive to disruption and to make proactive mitigating decisions by taking into account risk predictive occurrence.

References

Agamez-Arias, A.-D.-M., and Moyano-Fuentes, J. (2017). Intermodal transport in freight distribution: A literature review. *Transport Reviews*, Vol. 37(6), pp. 782-807.

Agbo, A. A., Li, W., Atombo, C., Lodewijks, G., and Zheng, L. (2017). Feasibility study for the introduction of synchromodal freight transportation concept. *Cogent Engineering*, Vol. 4(1), pp. 1305649.

Aghalari, A., Nur, F., and Marufuzzaman, M. (2020). A Bender's based nested decomposition algorithm to solve a stochastic inland waterway port management problem considering perishable product. *International Journal of Production Economics*, Vol. 229, pp. 107863.

Alessandrini, A., Mazzarella, F., and Vespe, M. (2019). Estimated Time of Arrival Using Historical Vessel Tracking Data. *IEEE Transactions on Intelligent Transportation Systems*, Vol. 20(1), pp. 7-15.

Allen, T. R., McLeod, G., and Hutt, S. (2021). Sea level rise exposure assessment of US East Coast cargo container terminals. *Maritime Policy & Management*, Vol. 0(0), pp. 1-23.

Alyami, H., Lee, P. T.-W., Yang, Z., Riahi, R., Bonsall, S., and Wang, J. (2014). An advanced risk analysis approach for container port safety evaluation. *Maritime Policy & Management*, Vol. 41(7), pp. 634-650.

Amador, C., Emond, J.-P., and Nunes, M. C. N. (2009). Application of RFID technologies in the temperature mapping of the pineapple supply chain. *Sensing and Instrumentation for Food Quality and Safety*, Vol. 3(1), pp. 26-33.

Andrews, D. J., Pennetti, C. A., Collier, Z. A., Polmateer, T. L., and Lambert, J. H. (2020). Segmented Identification of Disruptive Settings on Transportation Corridors. In G. Zhang (Éd.), International Conference on Transportation and Development 2020—Traffic and Bike/Pedestrian Operations, No. 2020, pp. 147-158.

Bălan, C. (2020). The disruptive impact of future advanced ICTs on maritime transport: A systematic review. *Supply Chain Management*, Vol. 25(2), pp. 157-175.

Baykasoğlu, A., Subulan, K., Taşan, A. S., and Dudaklı, N. (2019). A review of fleet planning problems in single and multimodal transportation systems. *Transportmetrica A: Transport Science*, Vol. 15(2), pp. 631-697.

Bendriss, S., and Benabdelhafid, A. (2011). Multimodal transport information system: Modelling approach for goods traceability. *International Journal of Business Information Systems*, Vol. 7(4), pp. 365-387.

Bentaleb, F., Mabrouki, C., and Semma, A. (2015). A Multi-Criteria Approach for Risk Assessment of Dry Port-Seaport System. *Supply Chain Forum*, Vol. 16(4), pp. 32-49.

Beskovnik, B., and Golnar, M. (2020). Eliminating barriers for sustainable transport systems on maritime Silk Road and baltic-adriatic corridor under BRI. In *SUSTAINABILITY*, Vol. 12(8), pp. 7412.

Bhatti, O. K., and Hanjra, A. R. (2019). Development prioritization through analytical hierarchy process (AHP)—Decision making for port selection on the one belt one road. *Journal of Chinese Economic and Foreign Trade Studies*, Vol. 12(3), pp. 121-150.

Bollen, A. F., Riden, C. P., and Opara, L. U. (2006). Traceability in postharvest quality management. *International Journal of Postharvest Technology and Innovation*, Vol. 1(1), pp. 93-105.

Bukkapatnam, S. T. S., and Komanduri, R. (2007). Container integrity and condition monitoring using RF vibration sensor tags. Proceedings of the 3rd IEEE International Conference on Automation Science and Engineering, IEEE CASE 2007, No. 3, pp. 585-590.

Cai, H., Hu, Z.-H., and Liu, W. (2009). Container process flow visualization by spatial location technologies. PACIIA 2009 - 2009 2nd Asia-Pacific Conference on Computational Intelligence and Industrial Applications, No. 2, pp. 131-134.

Cao, X., and Lam, J. S. L. (2019). Simulation-based severe weather-induced container terminal economic loss estimation. *Maritime Policy & Management*, Vol. 46(1), pp. 92-116.

Castelein, B., Geerlings, H., and Van Duin, R. (2020). The reefer container market and academic research : A review study. *Journal of Cleaner Production*, Vol. 256, pp. 120654.

Chang, K.-Y., Liu, C.-P., Huang, M.-L., Shen, J.-H., and Ding, J.-F. (2020). Implementation of Cargo Image System Via QR Code for Export Containers : Case Study of the Keelung Port. *Marine Technology Society Journal*, Vol. 54(1), pp. 97-109.

Chargui, K., Zouadi, T., El Fallahi, A., Reghioui, M., and Aouam, T. (2020). A quay crane productivity predictive model for building accurate quay crane schedules. *Supply Chain Forum*, Vol. 22(2), pp. 136-156.

Chen, C.-Y., Ding, J.-F., Liang, G.-S., and Chou, T.-Y. (2018). Applying fuzzy grey quality function deployment to identify solutions for improving safety of container terminal loading and unloading operations. *Proceedings of the Institution of Mechanical Engineers Part M-Journal of Engineering for the Maritime Environment*, Vol. 232(3), pp. 276-292.

Chen, D., Wang, X., Nelson, P., Li, Y., Zhao, N., Zhao, Y., Lang, J., Zhou, Y., and Guo, X. (2017). Ship emission inventory and its impact on the PM2.5 air pollution in Qingdao Port, North China. *Atmospheric Environment*, Vol. 166, pp. 351-361.

Chen, T. C. (2005). RFID and sensor-based container content visibility and seaport security monitoring system. In E. M. Carapezza (Éd.), *Sensors, and Command, Control, Communications, and Intelligence (C31) Technologies for Homeland Security and Homeland Defense IV, Pts 1 and 2* Vol. 5778, p. 151-159.

Cominelli, S., Halliday, W. D., Pine, M. K., Hilliard, R. C., Lawson, J. W., Duman, N., and Devillers, R. (2020). Vessel noise in spatially constricted areas : Modeling acoustic footprints of large vessels in the Cabot Strait, Eastern Canada. *Ocean & Coastal Management*, Vol. 194, pp. 105255.

Coppolino, L., D'Antonio, S., Formicola, V., Oliviero, F., and Romano, L. (2011). *On the security of the terminal operations for container shipping in multimodal transport : The SIS-TEMA project*. 6th International Conference on Risks and Security of Internet and Systems, No. 6, pp. 1-6.

Cullinane, K., Tseng, P.-H., and Wilmsmeier, G. (2016). Estimation of container ship emissions at berth in Taiwan. *International Journal of Sustainable Transportation*, Vol. 10(5), pp. 466-474.

Do, N. A. D., Nielsen, I. E., Chen, G., and Nielsen, P. (2016). A simulation-based genetic algorithm approach for reducing emissions from import container pick-up operation at container terminal. *Annals of Operations Research*, Vol. 242(2), pp. 285-301.

Dorri, A., Kanhere, S. S., and Jurdak, R. (2018). Multi-Agent Systems : A Survey. *IEEE Access*, Vol. 6, pp. 28573-28593.

Dua, A., and Sinha, D. (2019). Quality of multimodal freight transportation: A systematic literature review. *World Review of Intermodal Transportation Research*, Vol. 8(2), pp. 167-194.

Emenike, C. C., Eyk, N. P. V., and Hoffman, A. J. (2016). Improving Cold Chain Logistics through RFID temperature sensing and Predictive Modelling. *19th International Conference on Intelligent Transportation Systems (ITSC)*, No. 19, pp. 2331-2338.

Expósito-Izquierdo, C., Melián-Batista, B., and Moreno-Vega, J. M. (2018). A review of soft computing techniques in maritime logistics and its related fields. *Studies in Fuzziness and Soft Computing*, Vol. 360, pp. 1-23.

Fan, L., and Wilson, W. W. (2012). Impacts of congestion and stochastic variables on the network for US container imports. *Journal of Transport Economics and Policy*, Vol. 46(3), pp. 381-398.

Fan, L., Wilson, W. W., and Dahl, B. (2012). Congestion, port expansion and spatial competition for US container imports. *Transportation Research Part E: Logistics and Transportation Review*, Vol. 48(6), pp. 1121-1136.

Fan, Y., Behdani, B., and Bloemhof-Ruwaard, J. M. (2020). Reefer logistics and cool chain transport: A systematic review and multi-actor system analysis of an un-explored domain. *European Journal of Transport and Infrastructure Research*, Vol. 20(2), pp. 1-35.

Filina-Dawidowicz, L., Możdrzeń, D., and Stankiewicz, S. (2020). Integrated Approach for Planning of Intermodal Food Transport Chains Considering Risk Factors. *Communications in Computer and Information Science*, Vol. 1307, pp. 319-332.

Folinas, D., Aidonis, D., Mallidis, I., and Papadopoulou, M. (2015). Identification of Container Handling Procedures. In M. Vidovic, M. Kilibarda, S. Zecevic, M. Miljus, and G. Radivojevic (Éds.). Proceedings of the 2nd Logistics International Conference, pp. 99-104.

Fotuhi, F., and Huynh, N. (2017). Reliable Intermodal Freight Network Expansion with Demand Uncertainties and Network Disruptions. *Networks and Spatial Economics*, Vol. 17(2), pp. 405-433.

Fri, M., Douaioui, K., Mabrouki, C., and El Alami, S. (2021). Reducing Inconsistency in Performance Analysis for Container Terminals. *International Journal of Supply and Operations Management*, Vol. 8(3), pp. 328-346.

Fruth, M., and Teuteberg, F. (2017). Digitization in maritime logistics—what is there and what is missing? *Cogent Business & Management*, Vol. *4*(1), pp. 1411066.

Gallo, A., Accorsi, R., Baruffaldi, G., and Manzini, R. (2017). Designing sustainable cold chains for long-range food distribution : Energy-effective corridors on the Silk Road Belt. *Sustainability (Switzerland)*, Vol. 9(11), pp. 2044.

Giusti, R., Iorfida, C., Li, Y., Manerba, D., Musso, S., Perboli, G., Tadei, R., and Yuan, S. (2019). Sustainable and de-stressed international supply-chains through the SYNCHRO-NET approach. *Sustainability (Switzerland)*, Vol. 11(4), pp. 1083.

Gourc, D. (2006). Vers un modèle général du risque pour le pilotage et la conduite des activités de biens et de services : Propositions pour une conduite des projets et une gestion des risques intégrées. Institut national polytechnique de Toulouse.

Güller, M., Koc, E., Hegmanns, T., Henke, M., and Noche, B. (2015). A simulation-based decision support framework for real-time supply chain risk management. *International Journal of Advanced Logistics*, Vol. 4(1), pp. 17-26.

Gunes, B., Kayisoglu, G., and Bolat, P. (2021). Cyber security risk assessment for seaports : A case study of a container port. *Computers & Security*, Vol. 103, pp. 102196.

Guo, Z. X., Ngai, E. W. T., Yang, C., and Liang, X. (2015). An RFID-based intelligent decision support system architecture for production monitoring and scheduling in a distributed manufacturing environment. *International Journal of Production Economics*, Vol. 159, pp. 16-28.

Hansut, L., David, A., and Gasparik, J. (2017). The Critical Path Method as the Method for Evaluation and Identification of the Optimal Container Trade Route between Asia and Slovakia. In D. Dujak (Éd.), *Business Logistics in Modern Management*, Vol. 17, pp. 29-42.

Harris, I., Wang, Y., and Wang, H. (2015). ICT in multimodal transport and technological trends : Unleashing potential for the future. *International Journal of Production Economics*, Vol. 159, pp. 88-103.

He, J., Tan, C., Yan, W., Huang, W., Liu, M., and Yu, H. (2020). Two-stage stochastic programming model for generating container yard template under uncertainty and traffic congestion. *Advanced Engineering Informatics*, Vol. 43, pp. 101032.

He, J., Tan, C., and Zhang, Y. (2019). Yard crane scheduling problem in a container terminal considering risk caused by uncertainty. In *ADVANCED ENGINEERING INFORMATICS*, Vol. 39, pp. 14-24.

Heilig, L., and Voß, S. (2017). Information systems in seaports : A categorization and overview. *Information Technology and Management*, Vol. 18(3), pp. 179-201.

Heinold, A., and Meisel, F. (2020). Emission limits and emission allocation schemes in intermodal freight transportation. *Transportation Research Part E: Logistics and Transportation Review*, Vol. 141, pp. 101963.

Hervas-Peralta, M., Poveda-Reyes, S., Dolores Molero, G., Enrique Santarremigia, F., and Pastor-Ferrando, J.-P. (2019). Improving the Performance of Dry and Maritime Ports by Increasing Knowledge about the Most Relevant Functionalities of the Terminal Operating System (TOS). *Sustainability*, Vol. 11(6), pp. 1648.

Hilmola, O.-P., and Lättilä, L. (2013). Simulation modelling challenge of transportation logistics systems. *International Journal of Business Information Systems*, Vol. 14(4), pp. 429-442.

Hossain, N. U. I., Nur, F., Hosseini, S., Jaradat, R., Marufuzzaman, M., and Puryear, S. M. (2019). A Bayesian network based approach for modeling and assessing resilience : A case study of a full service deep water port. *Reliability Engineering and System Safety*, Vol. 189, pp. 378-396.

Hsu, W.-K. K., Huang, S.-H. S., and Wu, S.-W. (2021). A 3D continuous risk matrix for the assessment of operational safety in inland container terminals. Proceedings of the Institution of Mechanical Engineers Part M-Journal of Engineering for the Maritime Environment, pp. 147509022110514.

Hu, Z.-H., Yang, B., Huang, Y.-F., and Meng, Y.-P. (2010). Visualization framework for container supply chain by information acquisition and presentation technologies. *Journal of Software*, Vol. 5(11), pp. 1236-1242.

ISO 31000, *Risk management – Guidelines (2018). Edition. 1,* Published in Switzerland.

Jiang, M., and Lu, J. (2020). The analysis of maritime piracy occurred in Southeast Asia by using Bayesian network. *Transportation Research Part E: Logistics and Transportation Review*, Vol. 139, pp. 101965.

Kontovas, C., and Psaraftis, H. N. (2011). Reduction of emissions along the maritime intermodal container chain : Operational models and policies. *Maritime Policy & Management*, Vol. 38(4), pp. 451-469.

Lack, D. A., Cappa, C. D., Langridge, J., Bahreini, R., Buffaloe, G., Brock, C., Cerully, K., Coffman, D., Hayden, K., Holloway, J., Lerner, B., Massoli, P., Li, S.-M., McLaren, R., Middlebrook, A. M., Moore, R., Nenes, A., Nuaaman, I., Onasch, T. B., … Williams, E. (2011). Impact of Fuel Quality Regulation and Speed Reductions on Shipping Emissions : Implications for Climate and Air Quality. *Environmental Science & Technology*, Vol. 45(20), pp. 9052-9060.

Lam, J. S. L., Liu, C., and Gou, X. (2017). Cyclone risk mapping for critical coastal infrastructure : Cases of East Asian seaports. *Ocean & Coastal Management*, Vol. 141, pp. 43-54.

Lättilä, L., and Saranen, J. (2011). Multimodal transportation risk in gulf of Finland region. *World Review of Intermodal Transportation Research*, Vol. 3(4), pp. 376-394.

Lee, H. L. (1993). Design for Supply Chain Management : Concepts and Examples. In R. K. Sarin (Éd.), *Perspectives in Operations Management : Essays in Honor of Elwood S. Buffa*, pp. 45-65.

Li, W., Hilmola, O.-P., and Panova, Y. (2019). Container sea ports and dry ports : Future CO2 emission reduction potential in China. *Sustainability (Switzerland)*, Vol. 11(6), pp. 1515.

Li, X., Kuang, H., and Hu, Y. (2020). Using System Dynamics and Game Model to Estimate Optimal Subsidy in Shore Power Technology. *IEEE Access*, Vol. 8, pp. 116310-116320.

Lim, G. J., Cho, J., Bora, S., Biobaku, T., and Parsaei, H. (2018). Models and computational algorithms for maritime risk analysis : A review. *Annals of Operations Research*, Vol. 271(2), pp. 765-786.

Liu, B., and Wang, Y. (2021). Simulation-based emission calculation method for container terminal production operation system. *IOP Conference Series: Earth and Environmental Science*, Vol. 638, pp. 012028.

Longo, F., Mirabelli, G., and Bruzzone, A. (2005). Container handling policy design by simulation framework. *International Workshop on Harbour, Maritime and Multimodal Logistics Modeling and Simulation, HMS 2005, Held at the International Mediterranean Modeling Multiconference, I3M 2005,* pp. 69-74.

Longo, F., and Ören, T. (2008). Supply chain vulnerability and resilience: A state of the art overview, 20th European Modeling and Simulation Symposium, EMSS 2008, No. 20, pp. 527-533.

Longo, F., Mirabelli, G., and Tremori, A. (2009). Simulation, risks modeling and sensors technologies for container terminals security. 21st European Modeling and Simulation Symposium, EMSS 2009. Scopus, No. 21, pp. 1-7.

Ma, Q., Wang, W., Peng, Y., and Song, X. (2018). An optimization approach to the intermodal transportation network in fruit cold chain, considering cost, quality degradation and carbon dioxide footprint. *Polish Maritime Research*, Vol. 25(1), pp. 61-69.

Mahmood, S., Hasan, R., Ullah, A., and Sarker, K. U. (2019). SMART security alert system for monitoring and controlling container transportation. 2019 4th MEC International Conference on Big Data and Smart City, ICBDSC 2019, No. 19, pp. 1-5.

Mar-Ortiz, J., Gracia, M. D., and Castillo-García, N. (2018). Challenges in the design of decision support systems for port and maritime supply chains. *Studies in Computational Intelligence*, Vol. 764, pp. 49-71.

Marquès, G. (2010). *Management des risques pour l'aide à la gestion de la collaboration au sein d'une chaîne logistique : Une approche par simulation* [Phd]. Institut National Polytechnique de Toulouse (INP Toulouse).

Matsukura, H., Udommahuntisuk, M., Yamato, H., and Dinariyana, A. A. B. (2010). Estimation of CO2 reduction for Japanese domestic container transportation based on mathematical models. *Journal of Marine Science and Technology*, Vol. 15(1), pp. 34-43.

Meijer, R. (2017). ETA prediction: Predicting the ETA of a container vessel based on route identification using AIS data.

Mennis, E., Platis, A., Lagoudis, I., and Nikitakos, N. (2008). Improving port container terminal efficiency with the use of Markov theory. *Maritime Economics and Logistics*, Vol. 10(3), pp. 243-257.

Miller-Hooks, E., Chen, L., Nair, R., and Mahmassani, H. S. (2009). Security and mobility of intermodal freight networks. *Transportation Research Record*, Vol. 2137, pp. 109-117.

Mueller, R. (2008). Developing a Security Event Management System for intermodal transport. *Dynamics in Logistics*, pp. 405-412.

Munuzuri, J., Onieva, L., Cortes, P., and Guadix, J. (2020). Using IoT data and applications to improve port-based intermodal supply chains. *Computers & Industrial Engineering*, Vol. 139, pp. 105668.

Muñuzuri, J., Onieva, L., Escudero Santana, A., and Cortés, P. (2016). Impacts of a Tracking and Tracing System for Containers in a Port-Based Supply Chain. *Brazilian Journal of Operations & Production Management*, Vol. 13(3), pp. 352–359.

Nguyen, S. (2020). A risk assessment model with systematical uncertainty treatment for container shipping operations. *Maritime Policy & Management*, Vol. 47(6), pp. 778-796.

Nguyen, S., and Wang, H. (2018). Prioritizing operational risks in container shipping systems by using cognitive assessment technique. *Maritime Business Review*, Vol. 3(2), pp. 185-206.

Onut, S., Tuzkaya, U. R., and Torun, E. (2011). Selecting container port via a fuzzy ANP-based approach : A case study in the Marmara Region, Turkey. *Transport Policy*, Vol. 18(1), pp. 182-193.

Ouedraogo, C. A., ROSEMONT, C., Namakiaraghi, S., Montarnal, A., and Gourc, D. (2020). Maritime risks taxonomy: A structured literature review of maritime risks classification. MOSIM’20 - 13ème Conférence internationale de Modélisation, Optimisation et Simulation, No. 13, pp 1-17.

Ouedraogo, C. A., Namakiaraghi, S., Rosemont, C., Montarnal, A., Lauras, M., and Gourc, D. (2020). Traceability and risk management in multi-modal container transport: A small—Scale review of methods and technologies. Proceedings - 2020 5th International conference on logistics operations management (GOL), No. 5, pp. 296-302.

Pallotta, G., Vespe, M., and Bryan, K. (2013). Vessel Pattern Knowledge Discovery from AIS Data: A Framework for Anomaly Detection and Route Prediction. *Entropy*, Vol. 15(6), pp. 2218-2245.

Pant, R., Barker, K., Grant, F. H., and Landers, T. L. (2011). Interdependent impacts of inoperability at multi-modal transportation container terminals. *Transportation Research Part E: Logistics and Transportation Review*, Vol. 47(5), pp. 722-737.

Papert, M., Rimpler, P., and Pflaum, A. (2016). Enhancing supply chain visibility in a pharmaceutical supply chain Solutions based on automatic identification technology. *International Journal of Physical Distribution & Logistics Management*, Vol. 46(9), pp. 859-884.

Park, Y. I., Lu, W., Nam, T. H., and Yeo, G. T. (2019). Terminal Vitalization Strategy through Optimal Route Selection Adopting CFPR Methodology. *Asian Journal of Shipping and Logistics*, Vol. 35(1), pp. 41-48.

Parolas, I. (2016). *ETA prediction for containerships at the Port of Rotterdam using Machine Learning Techniques*. Delft University of technology.

Pinakpani, P., Polisetty, A., N Rao, G. B., Harrison Sunil, D., Kumar, B. M., Deepthi, D., and Sidhireddy, A. (2020). An algorithmic approach for maritime transportation. *International Journal of Advanced Computer Science and Applications*, Vol. 2, pp. 764-775.

Potgieter, L., Goedhals-Gerber, L. L., and Havenga, J. (2020). Risk Profile of Weather and System-Related Port Congestion for the Cape Town Container Terminal. *Southern African Business Review*, Vol. 24, pp. 6149.

Qiao, W., Haghani, A., and Hamedi, M. (2013). A Nonparametric Model for Short-Term Travel Time Prediction Using Bluetooth Data. *Journal of Intelligent Transportation Systems*, Vol. 17(2), pp. 165-175.

Sahin, B., and Soylu, A. (2020). Multi-Layer, Multi-Segment Iterative Optimization for Maritime Supply Chain Operations in a Dynamic Fuzzy Environment. *IEEE Access*, Vol. 8, pp. 144993-145005.

Sahnoun, A., and Maamri, R. (2015). Petri Net Modeling Dynamic Context of Container For Risk Management A Case Study of Le Havre Seaport. 2015 Ieee/Acs 12th International Conference of Computer Systems and Applications (Aiccsa), No. 12, pp. 1-8.

Šakalys, R., Sivilevičius, H., Miliauskaitė, L., and Šakalys, A. (2019). Investigation and evaluation of main indicators impacting synchromodality using ARTIW and AHP methods. *Transport*, Vol. 34(3), pp. 300-311.

Schoen, Q., Pinon-Baca, D., Lauras, M., Fontanili, F., and Truptil, S. (2018). A new transport management system design considering the upcoming logistics environment and the sensitive products supply chains. ILS 2018 - 7th International Conference on Information Systems, Logistics and Supply Chain, No 7, pp. 286-295.

Shen, L., Zhu, G., Qian, X., Zhang, L., Wang, Y., and Shi, X. (2019). Risk Analysis of Cold Logistics Chains in Maritime Transportation. 5th International Conference on Transportation Information and Safety, No. 5, pp. 1152-1162.

Shibasaki, R., Azuma, T., Yoshida, T., Teranishi, H., and Abe, M. (2017). Global route choice and its modelling of dry bulk carriers based on vessel movement database: Focusing on the Suez Canal. *Research in Transportation Business and Management*, Vol. 25, pp. 51-65.

Slaczka, W., Pietrusewicz, K., and Marcinek, M. (2017). Intelligent Container in Water—Land Transport. MBSE Approach for System Design. In J. Mikulski (Éd.), *Smart Solutions in Today’s Transport*, Vol. 715, pp. 344-359.

Swieboda, J. (2016). System resilience at an intermodal transshipment node. In *CLC 2015:* Carpathian logistics congress -conference proceeding, pp. 502-511.

Tadic, S., Krstic, M., Roso, V., and Brnjac, N. (2020). Dry port terminal location selection by applying the hybrid grey MCDM model. *Sustainability (Switzerland)*, Vol. 12(17), pp. 6983.

Tao, X., and Wu, Q. (2021). Energy consumption and CO2 emissions in hinterland container transport. *Journal of Cleaner Production*, Vol. 279, pp. 123394.

Tran, T. H., Dobrovnik, M., and Kummer, S. (2018). Supply chain risk assessment: A content analysis-based literature review. *International Journal of Logistics Systems and Management*, Vol. 31(4), pp. 562-591.

Tsao, Y.-C., and Linh, V. T. (2018). Seaport- dry port network design considering multimodal transport and carbon emissions. *Journal of Cleaner Production*, Vol. 199, pp. 481-492.

Tseng, W.-J., Ding, J.-F., Hung, S.-H., and Poma, W. (2019). Risk Management of Terminal on-Site Operations for Special Bulk Cargos in Taiwan. *International Journal of Maritime Engineering*, Vol. 161, pp. 117-128.

Tu, E., Zhang, G., Mao, S., Rachmawati, L., and Huang, G.-B. (2020). Modeling Historical AIS Data For Vessel Path Prediction: A Comprehensive Treatment. *ArXiv, abs/2001.01592*.

UNECE, United Nations, 2020. (2020). Trade facilitation white paper on smart containers; Real-time smart container data for supply chain excellence.

Urciuoli, L. (2018). An algorithm for improved ETAs estimations and potential impacts on supply chain decision making. *Procedia Manufacturing*, Vol. 25, pp. 185-193.

Vallejo-Pinto, J. A., Garcia-Alonso, L., Álvarez Fernández, R., and Mateo-Mantecón, I. (2019). Iso-emission map : A proposal to compare the environmental friendliness of short sea shipping vs road transport. *Transportation Research Part D: Transport and Environment*, Vol. 67, pp. 596-609.

Vilko, J. P. P., and Hallikas, J. M. (2012). Risk assessment in multimodal supply chains. *International Journal of Production Economics*, Vol. 140(2), pp. 586-595.

Vilko, J., Ritala, P., and Hallikas, J. (2019). Risk management abilities in multimodal maritime supply chains: Visibility and control perspectives. *Accident Analysis & Prevention*, Vol. 123, pp. 469-481.

Wattanakul, S., Henry, S., Bentaha, M. L., Reeveerakul, N., and Ouzrout, Y. (2018). Improvement of the Containerize Performance based on the Unitary Traceability of Smart Logistics Units. 15th IFIP International Conference on Product Lifecycle Management (PLM 2018), No. 15, pp. 410-419.

Wattanakul, S., Reeveerakul, N., Henry, S., and Ouzrout, Y. (2019). Uncertainty handling in containerized logistics: Unitary Traceability Object approach. *International Conference on Software, Knowledge, Information Management and Applications (SKIMA)*, No. 13, pp. 1-7.

Wide, P. (2020). Real-time information for operational disruption management in hinterland road transport. *World Review of Intermodal Transportation Research*, Vol. 9(4), pp. 358-375.

Wong, E. Y. C., Tai, A. H., Lau, H. Y. K., and Raman, M. (2015). An utility-based decision support sustainability model in slow steaming maritime operations. *Transportation Research Part E-Logistics and Transportation Review*, Vol. 78, pp. 57-69.

Yan, W., He, J., and Trappey, A. J. C. (2019). Risk-aware supply chain intelligence: AI-enabled supply chain and logistics management considering risk mitigation. *Advanced Engineering Informatics*, Vol. 42, pp. 100976.

Yang, Y.-L., Ding, J.-F., Chiu, C.-C., Shyu, W.-H., Tseng, W.-J., and Chou, M.-T. (2016). Core risk factors influencing safe handling operations for container terminals at Kaohsiung port. *Proceedings of the Institution of Mechanical Engineers Part M-Journal of Engineering for the Maritime Environment*, Vol. 230(2), pp. 444-453.

Zhang, C., Bin, J., Wang, W., Peng, X., Wang, R., Halldearn, R., and Liu, Z. (2020). AIS data driven general vessel destination prediction: A random forest based approach. *Transportation Research Part C: Emerging Technologies*, Vol. 118, pp. 102729.

Zhang, Z., Zhang, D., Tavasszy, L. A., and Li, Q. (2020). Multicriteria intermodal freight network optimal problem with heterogeneous preferences under belt and road initiative. *Sustainability (Switzerland)*, Vol. 12(24), pp. 1-24.

Zhao, Y., Zhou, J., Fan, Y., and Kuang, H. (2020). An Expected Utility-Based Optimization of Slow Steaming in Sulphur Emission Control Areas by Applying Big Data Analytics. *Ieee Access*, Vol. 8, pp. 3646-3655.

Zou, X., Tao, F., Jiang, P., Gu, S., Qiao, K., Zuo, Y., and Xu, L. (2016). A new approach for data processing in supply chain network based on FPGA. *The International Journal of Advanced Manufacturing Technology*, Vol. 84(1), pp. 249-260.