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# Maritime risks taxonomy: A structured literature review of maritime risks classification

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**ABSTRACT:** *The purpose of this paper is to investigate the multi-modal Maritime risk classification, which has shown a great global attention in recent years. Disruption and uncertainties in shipping companies are the result of random events which lead to drop performance throughout the maritime transportation supply chain and they severely impact international trade. This study provides an overview of multi-modal supply chain management by reviewing 131 articles in the risk management area. This work also provides a great analysis of transportation risks, their impacts and a risk typology on multi-modal maritime supply chains management. In addition, this paper contributes to the current risk management literature by proposing a novel risk typology that permits to determine which risk carriers and shippers involved in multi-modal containers transportation should address first, thereafter this typology could be used to build a decision support tool in order to detect and mitigate risks in real-time.*

**KEYWORDS:** *Risk, disruption, uncertainty, maritime container transport.*

## 1 INTRODUCTION

Maritime transportation is the most used transportation mode in international trades. Indeed, it represents 90% of international trades (Wendler-Bosco & Nicholson 2019). World traffic in containerized goods increased by 6.4% in 2018 (*Etude sur les transports maritimes 2018* 2018). This explains that maritime container supply chain becomes more and more dynamic and complex. Maritime container transport is a complex process because several stakeholders are involved, such as, the shipper (the company that sells its products), the buyer (the company or person to whom the products are sold), the carrier (the company which takes care of the organization of the transport from shipper warehouse to the arrival port), the shipping line (the company which deals with the maritime transport of products from departure port to arrival port) Fig 1. In an internal supply chain the shipper and buyer are the same actor.

Multi-modal maritime container transportation is exposed to various hazardous events that affect the supply chain of all the stakeholders involved in the transportation process (Wang, Xu, Peng, Zhou & Jiang 2020). These last years, disruptions due to

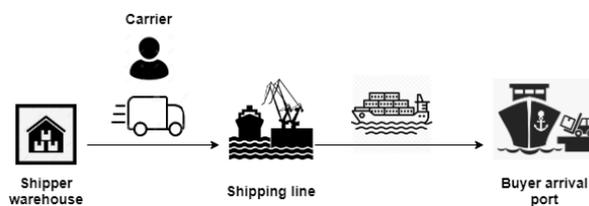


Figure 1 – Maritime stakeholders

maritime supply chain risks have impacted the performances of the companies (Ho, Zheng, Yildiz & Talluri 2015), this is why the management of maritime supply chains receives a great deal of attention in literature. In addition the recent epidemic world crisis, which has caused a disruption in multi-modal transportation, highlights the role of supply chain risk management for several business sectors. Many research works have been published on the identification, classification and assessment of risk factors in containers shipping. For example, (Vilko, Ritala & Hallikas 2019) provided a holistic and systemic view of risk visibility and control in maritime supply chains. (Abdel-Basset, Gunasekaran, Mohamed & Chilamkurti 2019) also proposed a framework for the assessment, management and evaluation of risks in a supply chain. However there is a lack of real-

time detection, quantification and mitigation of risks in multi-modal maritime supply chain in the literature. Real-time risk detection and quantification could help the supply chain decision-makers to be more proactive in risk assessment. These studies provide risk typologies according to dimensions such as external and internal risks or macro and micro risks, based on qualitative and quantitative analysis of supply chain risks. Typologies provided in the literature help the researchers and stakeholders involved in maritime container supply chain identify various risk types with their associated impacts. However, most of the time, they are not really suitable to be used for real-time detection of risks in multi-modal containerized transportation.

This work aims to provide a structured systematic literature review on multi-modal maritime supply chain risk management by identifying risk class and risk typologies proposed. Afterwards, these risk classes are used to propose a novel typology which will be the beginnings for construction of a decision support tool which will be used to detect and mitigate risks in real-time. Two main questions are addressed in this literature review:

1. What is the current state of the research in Risk management of Multi-modal Maritime Supply chain?
2. What are the gaps in the current research that future research should address?

This paper is structured in 5 sections and is based on the existing literature related to maritime supply chains risk management between 2005 and 2020. The second section presents research methods and frameworks used to carry out the systematic literature review. Section three presents an analysis of the set of the previously selected articles and, hence, provides the current state of the art about risk class in supply chain. Based on this state of the art, section four proposes a novel risk typology specifically designed for the real-time detection, quantification of the risks. The use of this typology by multi-modal maritime supply chains managers will finally be discussed in section Five.

## 2 RESEARCH FRAMEWORK

This section aims to detail the research methodology that was used to carry out the systematic literature review. In order to capture the most important and recent works published in supply chain risk management, within the maritime transport area, three main steps were executed (Fig 2):

- Articles collection

- Articles selection
- Articles analysis

### 2.1 Articles collection

This section details the article collection process, which is step 1 in the research framework illustrated in Fig 2. Four keywords: *risk*, *disruption*, *uncertainty* and *maritime container transport* have been identified to shape the request to select the most relevant articles on the scientific databases. As a result, the established request: "risk or disruption or uncertainty and maritime transport" was applied to the most relevant bibliographic databases such as *Science Direct*, *Springer*, *Taylor & Francis*, *Scopus* and *Web of science* and we limited the publication year between 2005 and 2020 in order to capture recent information. In addition, to ensure that all the articles brought up by the first request deal with container transportation, we refined the results with the keyword *container* for each database request. By considering only articles written in English identified in each databases we gathered 350 articles. After this collection, duplicates have been removed (39 articles).

### 2.2 Articles selection

The aim of this section is to present the articles selection process, which is step 2 in the research framework, in Fig 2. After having gathered the articles, the most relevant were selected to be analyzed. An article is considered relevant when its abstract contains the combination of "risk or disruption or uncertainty and maritime container transport". This permits to exclude works dealing with air transport and those not dealing with risks in maritime container transport. Hence, 149 articles have been removed from the previous collection.

After reading the introductions and conclusions of the remaining articles, 131 articles were finally selected and analyzed. An article is relevant in full reading phase when the article proposed a method to identify and/or assess container transportation risks or proposed a risk typology. This permits to discard all studies proposing risk management frameworks without really specifying risk class (Yang 2010) (Fig 2).

## 3 Articles analysis

The number of publications each year is indicated in Fig 4. The distribution of articles demonstrates the interest shown for several years in maritime container transport. The number of articles published has grown since 2017, the number of articles published in 2019 is twice the number published in 2018. The aim of this section is to identify different risk typologies, risk classes and their impacts proposed in

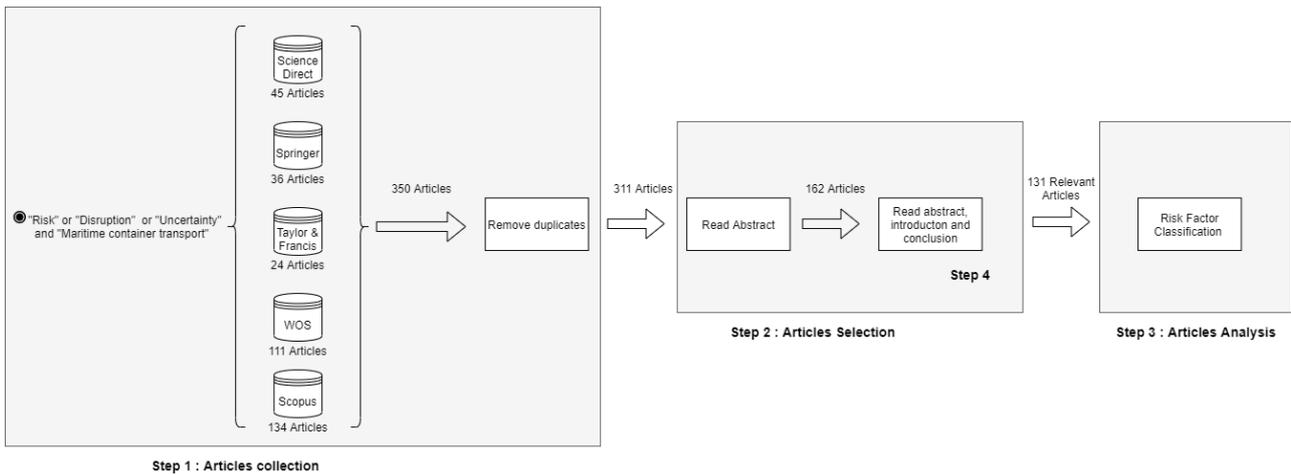


Figure 2 – Research Framework

the literature; it's the step 3 in research framework Fig 2. In addition, a comparison of solutions proposed by each paper with the research question they address (the research contribution in Maritime supply chain management).

Maritime supply chain risk management's aim is to identify and create mitigation techniques in order to avoid risks encountered during shipping. By analysing the 131 articles selected, only ten give a structured typology of risk factor. All the typologies proposed by the different authors can be grouped into three main categories: those who distinguish external and internal risk, those who classified macro and micro risk and those who classified risks occurred following supply chain flow (physical, information and financial flow). These typologies are more detailed in the following paragraphs :

- External and internal risk typology

On the other hand the authors in (Vilko et al. 2019) (Vilko & Hallikas 2012) (Abdel-Basset et al. 2019) (Li 2014) (Moslemi 2016) (Wan 2018) (Achurra-Gonzalez & al 2019) provided a holistic and systemic view of risk visibility and control in maritime supply chains by proposing two risk types, internal and external risk.

- Macro and Micro risk typology

The authors in (Ho et al. 2015) reviewed 224 articles between 2003 and 2013 and then proposed two types of risk, macro and micro risk factors. A macro risk is defined as a risk caused by natural disaster ( earthquake, weather-relate disasters, etc) and a micro risk (Demand risk, Manufacturing risk, supply risk and infrastructural risk) is defined as an operational risk occurring during transport activities. For analogy, macro risk may be assimilated to external risk and micro risk to internal risk.

- Classification following Supply chain flow

Some authors classified risks by following the supply chain flow. For example, the authors in (Tang & Nurmaya Musa 2011) investigated the research development in supply chain risk management by reviewing 138 articles between the years of 1995 and the first half of 2008. They identified 3 risk types: material, information and financial flow risk. In the same way, the authors in (Chang, Xu & Song 2016) also proposed classification of risks by following 3 main flows in supply chain (Information, Physical and Payment flow). The authors in (Tsai 2006) works on risk related to information acquisition.

The identified risk classes are assigned to each type of risk. These three typologies provide classification could help maritime supply chain stakeholders identify and quantify risk. However, the proposed typologies do not help determine what risks stakeholders should address first in order to increase the performance and the resilience of maritime container supply chain.



Figure 3 – Risk Management process

### 3.1 Most relevant source

It is important to note on the figure 4 that among all of the sources brought up by the bibliography research, the journal Maritime Policy / Management has published the most articles 13% between 2005

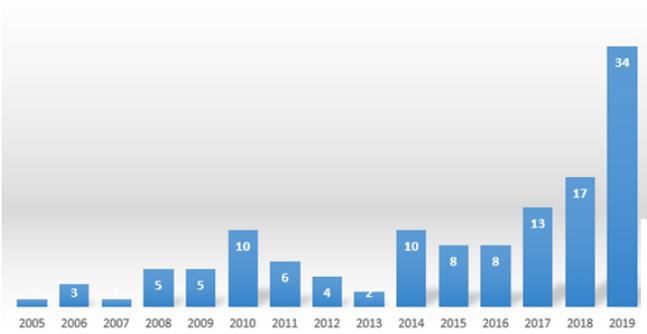


Figure 4 – Article distribution

and 2020 that deal with risk management in the maritime container transport. Maritime Economics / Logistics magazines and Transport Research Part come secondly with 5% of articles each. These sources provide articles proposing measures to address the risk classes in maritime transport area.

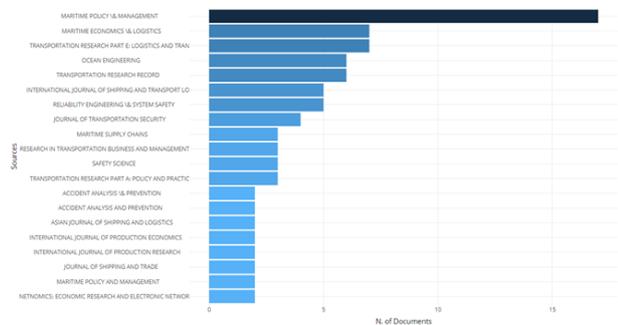


Figure 5 – Most relevant Source

### 3.2 Risk class identification

(Gourc 2006) define a risk as "the possibility that an event may occur whose occurrence would have impact (positive or negative) on the progress of the activity". A risk is characterized by two dimensions, the probability of occurrence and the severity of potential impacts. A risk class is defined as a family which regroups risks related to specific domain of multi-modal transport supply chain (supply, organization etc). Many studies propose methods to reduce these risks by following risk management framework steps, risk identification, risk evaluation, risk assessment and risk monitoring (see figure 3). Investigation methods like Failure Modes and Effects Analysis (FMEA) (Alyami, Yang, Riahi, Bonsall & Wang 2019), review of accident statistics (Kumar & Verruso 2008), Bayesian networks (Baksh, Abbassi, Garaniya & Khan 2018) and interviews with maritime and multi-modal transport experts permit to identify risk class. For instance, the authors in (Alyami, Lee, Yang, Riahi, Bonsall & Wang 2014) identify 76 risk sources and hazardous events in container port operations by using an advanced FMEA and different expert's knowledge in port operations. In the same way, the authors in (Yang 2010) and (Yang & Hsu 2018)

used a questionnaire survey and structural equation to examine maritime supply chain resilience. The literature review allows us to identify several risk class associated to risk typologies: Supply risk, Demand risk, Business risk, Operational risk, Environmental risk, Organizational risk, Infrastructural risk.

■ Supply ■ Demand ■ Business ■ Operational ■ Environmental ■ Organizational ■ Infrastructural

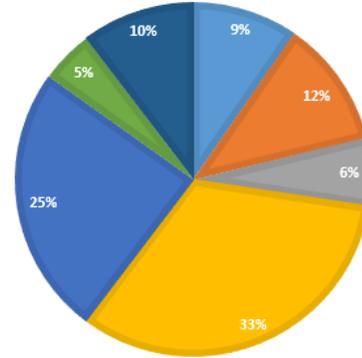


Figure 6 – Risk class distribution

#### 3.2.1 Supply risk

Also called logistical risk, the supply chain risks increase the probability to perturb the circulation of products through the supply chain. These risks include lack of equipment or bottlenecks in maritime routes, labor strike etc. For example the authors in (Hossain, Nur, Hosseini, Jaradat, Marufuzzaman & Puryear 2019b) identified supply risk class as the basic factors that could enhance the resilience of the port system in order to quantify the resilience of the port infrastructure by applying a Bayesian network. The authors in (Lam & Bai 2016) proposed supply risk class in external and internal risk classification (Port state inspections).

#### 3.2.2 Demand risk

Shipping lines face two types of customer demands: long-term demand and spot market demand" (Zheng, Li & Song 2017). The spot market demand uncertainty causes a risk-aversion attitude in maritime companies pricing strategies (Xing & Zhong 2017). Demand risk are related to unexpected customer demand. The authors in (Shibasaki, Azuma, Yoshida, Teranishi & Abe 2017) proposed a logit model to deal with these risks. To finish the authors, in (Choi, Beresford, Pettit & Bayusuf 2010) investigated on the aid supply chain operation in normal and extreme condition of Rwanda civil war in order to assess demand risk (demand fluctuation) during emergency movement.

#### 3.2.3 Business risk

Also called financial or economical risks "these risks include the stability of a supplier finance or man-

agement, or purchase and sale of supplier companies" (Abdel-Basset et al. 2019). The authors in (Wan, Yan, Zhang, Qu & Yang 2019) developed a model incorporating a fuzzy belief rule approach with Bayesian networks in order to assess business risks. (Drobetz, Schilling & Tegtmeier 2010) analyzed macroeconomic risk factors that drive expected stock returns in container shipping industry. The authors in (Li 2014) addressed the degree of risk of maritime transport nodes in Taiwan and Chinese Strait.

### 3.2.4 Operational risk

Also called technical or physical plant risks, these risks occur during the operational transport process. Operational risks include congestion, fire, terrorism, piracy, long waiting time, handling, stowage etc. The authors in (Yang, Ng & Wang 2014) introduce a novel fuzzy evidential reasoning approach to analyze operational risk factors (terrorism, hijacking) for port facility security. The authors in (Lam & Bai 2016) and (Lam, Lun & Bell 2019) proposed operational risk factor in external and internal risk classification (Ship collision or sinking, the condition of cargo-handling equipment and problems with document interpretation). These risks are the most dealt in the literature Fig 6. (Nguyen 2020).

### 3.2.5 Environmental risk

Maritime transportation often face to environmental risks and accidents that cause severe delay and financial lose which affect cargo flow (Achurra-Gonzalez & al 2019). These risks include uncertainty weather, natural disasters (earthquake, cyclone, flood, drought, volcanic eruption, seismic, hurricanes and tropical storms), political conflicts or man-made crises (civil unrest, war, political/tribal disturbance). The authors in (Hossain et al. 2019b) identifies environmental risks in order to use Bayesian network for quantify them. In the same way the authors in (Fan, Wrobel, Montewka, Gil, Wan & Zhang 2020) (Perez Lesprier, Long, Shoberg & Corns 2019) and (Gudelj, KrÄum & KrÄum 2008) cited environmental risks when they identify risk class that influence the navigation.

### 3.2.6 Organizational risk

Also called managerial or planning and control risks, "these risks occur due to inappropriate estimation and planning, which reach ineffective management" (Abdel-Basset et al. 2019). The authors in (Hossain et al. 2019b) and (Wan et al. 2019) identified organizational risks in order to use Bayesian network for quantify them. The authors in (Fabiano, Curro, Reverberi & Pastorino 2010) argued that organization of work and environmental conditions can affect occupational accident frequency in port. In the same way,

the authors in (Yang 2011) by following external and internal risk typology have identified risk perception on Chinese and Korean shipping companies, and also demonstrated the impact of organizational risks on shipping company performance.

### 3.2.7 Infrastructural risk

A failure of an infrastructure in a port or the degradation of a resource can lead to sever disruption in maritime supply chain. Infrastructural risks include information risk (lack of visibility or delay in transmission), lack of transportation mode and port capacity. The authors in (Hossain et al. 2019b) identified infrastructural risks in order to use Bayesian network for quantify them. The authors in (Fan et al. 2020) cited technological risk class when they identify risk factors that influence the navigation. The authors in (Wan et al. 2019) developed a model incorporating a fuzzy belief rule approach with Bayesian networks in order to assess infrastructural risks.

## 4 Risk taxonomy

The work of identifying and analyzing the typologies and risk classes carried out in section 3 makes it possible to propose a new typology which will be used for the detection of risks in real-time. In this section, the novel risk typology proposed in order to help shippers and carriers better assess risks is based on the risk classes identified in literature. This typology takes up the classification of risk classes according to logistical flows (physical and information flows) and include the context risk type which influences maritime container transportation. The proposed typology also provides a analysis of detectability of risks and potential impacts during shipment.

### 4.1 Detectability

We define risk detectability as the possibility for stakeholders involved in maritime supply chain to detect the risk when it occurs. Many authors agreed that supply chain visibility is one the key for risk management (Vilko & Hallikas 2012).

### 4.2 Impacts

"All risks can be minimized to a manageable level by employing the proper mitigation strategy" (Vilko et al. 2019). Mitigation strategy in risk management framework are used to reduce the risk occurrence probability or the risk severity. The mitigation strategies proposed by authors in the field of supply chain risk management use various quantitative and qualitative methods to reduce risk impact severity. For example the authors in (Abdel-Basset et al. 2019) and (Vilko & Hallikas 2012) propose

Risk class	Risks	Definition
Supply risk	Lack of equipment	Lack of appropriate equipment for container loading or unloading
	Bottlenecks	Bottlenecks in arrival port
	Labor strike	Docker strike could affect transport plan
	Bad handling	Bad handling during container loading
	Lack of human resource	Lack of human resource for container loading or unloading
	Unstable maintenance	Poor maintenance on transportation resources
	Carelessness	Carelessness on container or goods handling
	Lack of motivation among workforce	Lack of motivation of human resource during container loading or unloading
Demand risk family	Lack of skilled workers	Lack of skilled dockers
	unexpected customer demand	Unexpected variation on customer demand
Business risk	Purchase and sale of supplier companies	Lack of transportation mode provider
	Production cost	Unexpected production cost variation
	Fuel cost	Unexpected Fuel cost variation
	Storage cost	Unexpected Storage cost variation
	Funding	Lack of finance
	Tax changes	Unexpected Tax cost variation
	Debt ratio changes	Unexpected variation of debt ratio
	Return on investment changes	Incorrect estimate of return on investment
Operational risk	Route deviation	Exit the established route plan regardless of transport mode.
	Congestion	Congestion in port due to strike, or lack of resource (equipment, dock...)
	Fire	Fire in the boat during shipment.
	Terrorism	Use of containers to transport weapons
	Unexpected door opening	Unexpected door opening regardless transport mode.
	Unexpected Temperature variation	Unexpected temperature variation regardless transport mode.
	Unexpected Humidity variation	Unexpected humidity variation regardless transport mode.
	Container/ Goods damage	Damage to container/ Goods during container transit and in port during transshipment.
	Container/ Good theft	The container or Goods is stolen by pirates during transport or at the port.
	Container Lost	The container was loaded in the wrong boat or landed in the wrong port.
	Piracy	Theft, hijacking of the container by persons outside the crew
	Long waiting time	Long waiting time in port due to lack of resource of transport mode
	Stowage	Shocks due to stowage
	Ship collision	Container damage due to ship collision
	Condition of cargo handling	Handling at port could damage container or goods
	Explosion	Explosion due to transportation of dangerous goods
Shocks	Shocks due to bad handling of containers	
Environmental risk	Uncertainty weather	Bad weather like thunderstorm could affect transport plan
	Natural disasters (earthquake, cyclone, flood...)	Natural disasters like earthquake could affect route plan
	Political conflicts	Instability in export, import or transshipment country
	Man made crises (civil unrest, war...)	Civil war could affect transport plan
Organizational risk	Problems with document interpretation	Transport condition not respected due to misunderstanding of transport document
	Inappropriate estimation of planning	Inappropriate estimation of planning due to lack of information
Infrastructural risk	Lack of visibility	No visibility of container current position
	Delay in transmission	Asynchronous transmission of information between maritime transport stakeholders.
	Lack of transportation mode	Lack of appropriate transport mode in multi-modal transport
	Port capacity	Congestion due to small port capacity
	Lack of relevant information	Lack of anticipation in physical flow due to lack of relevant information
	Cyber-attack	Attack in information system

Table 1 – Risk class

Risk class	Risk management Process			
	Risk Identification	Risk evaluation	Risk assessment	Risk monitoring
Supply risk	(Hossain et al. 2019b) (Fan et al. 2020) (Lam & Bai 2016) (Ho et al. 2015)	(Li, Chen, Govindan & Jin 2018) (Li, Qi & Lee 2015)	(Mani, Delgado, Hazen & Patel 2017) (Alderson, Funk & Gera 2018) (Li et al. 2018) (Li, Qi & Lee 2015) (Hall & O'Brien 2018) (Hartman & Clott 2015)	
Demand risk	(Zheng et al. 2017) (Lam & Bai 2016)	(Shibasaki et al. 2017) (Wang, Wang, Qu, Liu & Jin 2014) (Zheng, Jin & Hu 2016) (Wang, Meng & Wang 2012) (Yin, Chen & Xiao 2019) (Justice & al 2016) (Alexandridis & al 2018)	(Shibasaki et al. 2017) (Choi et al. 2010) (Wang et al. 2014) (Zheng et al. 2016) (Wang et al. 2012) (Mani et al. 2017) (Lee & Moon 2020) (Jeon & Yeo 2017) (Alexandridis & al 2018)	(Cruz & Marques 2012) (Alexandridis & al 2018)
Business risk	(Abdel-Basset et al. 2019) (Yang 2011)	(Drobetz et al. 2010) (Li 2014) (Fabiano et al. 2010)	(Wan et al. 2019) (Li 2014) (Wang et al. 2020)	(Cruz & Marques 2012)
Operational risk	(Lam & Bai 2016) (Lam et al. 2019) (Pinto & Talley 2006) (Nguyen 2020) (Alyami et al. 2019) (Wan & Yan 2019) (Baksh et al. 2018) (Gudelj et al. 2008) (Chen, & al. 2019) (Baalisampang & al. 2018) (Lewis, Erera, Nowak & White 2013) (Justice & al 2016) (Kraska & Wilson 2009) (Murphy 2007) a (Endrina & al. 2019) (Mirza & Verdier 2008) (Lu, Chang, Hsu & Metaparti 2010) (Ellis 2010)	(Yang et al. 2014) (Zhao, Yan & Zhang 2017) (Nguyen, Chen, Du & Shi 2019) (Li, He, Sun & Cao 2019) (Celik, Lavasani & Wang 2010) (Park, Lu, Nam & Yeo 2019) (Stavrou, Ventikos & Yang 2018) (Yang & Hsu 2018) (Yuan, Hsieh & Su 2019) (Kumar & Verruso 2008) (Yang, Wang, Bonsall & Fang 2009) (Alyami et al. 2019) (Baksh et al. 2018) (Gudelj et al. 2008) (Mohseni & Thierry 2019) (Chen et al. 2019) (Baalisampang & al. 2018) (Lewis et al. 2013) (Justice & al 2016) (Kraska & Wilson 2009) (Murphy 2007) (Nogue-Alguero 2020) (Fan & Wilson 2012) (Pant, Barker, Grant & Landers 2011) (Talas & Menachof 2014) (Raymond 2006) (Shapiro & al 2018) (Ellis 2010)	(Celik et al. 2010) (Park et al. 2019) (Stavrou et al. 2018) (Kumar & Verruso 2008) (Yang et al. 2009) (Baksh et al. 2018) (Gudelj et al. 2008) (Baalisampang & al. 2018) (Shibasaki et al. 2017) (Saeed, Song & Andersen 2018) (Kelman 2008) (Lewis et al. 2013) (Justice & al 2016) (Murphy 2007) (Li et al. 2018) (Li, Qi & Lee 2015) (Li, Jin & Lu 2015) (Fan & Wilson 2012) (Lu et al. 2010) (Barnes & Oloruntoba 2005) (Behdani & al 2020) (Kontovas & Psaraftis 2011)	(Li, Qi & Lee 2015) (Li, Jin & Lu 2015)
Environmental risk	(Achurra-Gonzalez & al 2019) (Hossain et al. 2019b) (Fan et al. 2020) (Perez Lesprier et al. 2019) (Gudelj et al. 2008) (Lam & Bai 2016) (Wan & Yan 2019) (Singh, Soni & Badhotiya 2019) (Pouliasis & al 2018)	(Celik et al. 2010) (Yang & al 2018) (Wang, Kato & Shibasaki 2013) (Li 2014) (Li, Li & Lu 2019)	(Jian, Liu & Lam 2019) (Cao & Lam 2019) (Cheaitou & Cariou 2019) (Na & Shinozuka 2009) (Wu, Zhang & Wan 2019) (Hu, Yuan & Nian 2019) (Gou & Lam 2019) (Liu, Gong & Xiao 2018) (Baksh et al. 2018) (Ryan-Henry & Becker 2020) (Pant et al. 2011) (Calatayud, Mangan & Palacin 2017) (Wu, Wang, Yu & Wu 2019) (Iliopoulou & al. 2018) (Ivey, Rix, Werner & Erera 2010) (Mansouri, Lee & Aluko 2015) (Justice & al 2016)	(Choi et al. 2010)
Organizational risk	(Hossain et al. 2019b) (Wan et al. 2019) (Yang 2011) (Marlow 2010)	(Hossain et al. 2019b) (Wan et al. 2019)		(Yang 2011)
Infrastructural risk	(Hossain et al. 2019b) (Fan et al. 2020)	(Wan & Yan 2019) (Tsai 2006) (Gonzalez-Aregall & Bergqvist 2019) (Fan, Heilig & VoÅ 2015) (Singh et al. 2019) (Li 2014) (Lv, Jin & Hu 2020)	(Wan et al. 2019) (Chang et al. 2016) (Schauer, Polemi & Mouratidis 2019) (Li, Chen, Liao & Shi 2016)	(Cruz & Marques 2012)

Table 2 – Risk classes associated to risk management process

three types of risk impact in multi-modal transport (Time, Finance and Quality). Other authors like (Mohseni & Thierry 2019) question in negative socio-environmental impact of shipping industry. The table 2 presents the work carried out in the context of multi-modal risk management associate with step of risk management process.

This study consider the four types of risk impacts in maritime container transport:

- Delay impact: These impacts are linked to increasing of arrival time and lead time due to risks.
- Financial impact: These impacts are linked to losing of container or goods value and additional costs due to risks.
- Damage impact: These impacts are linked to losing of reputation for carrier and losing of goods quality for shipper due to risks.
- Environmental impact: These impacts are linked to increasing of carbon footprint due to risks.

These impacts have been quantified for shipper and carrier when risks occurs with help of qualitative interviews on maritime claims management experts.

### 4.3 Risk typology

For the proposed typology, risk classes for shippers and carriers are addressed. It's difficult for this typology to use external and internal or macro and micro proposed typology. Because what is external for the shipper can be internal for the carrier or vice versa. The classification according to supply chain flows has been retained.

The table 3 presents the novel proposed risk taxonomy to help carriers and shippers better manage risks in multi-modal transport supply chain. The first column of this table presents risks selected in the literature and confirmed with experts interviews. The physical flow risk type considers operational risks and supply risks. The information flow risk type considers infrastructural risks, demand risks and organizational risks. The context risk type includes environmental risks and business risks Table 3. The second column confirms the ability for shippers (SH) or carriers (CA) to detect risks when it's occurs. The last columns of this table assesses the possible impacts of this risk for carriers (CA) and shippers (SH) involved on the supply chain. For example, a route deviation can influence the arrival time of container, which will probably generate additional costs for the shipper who will receive the container late. In parallel, this route deviation can cause a loss of reputation for the carrier who does not respect the delivery time

given the contract and to finish this deviation can increase the carbon footprint for the two stakeholders involve on maritime supply chain due to the run-off from the established route plan.

## 5 Research implication and discussion

Many studies have been carried out in the field of maritime risk management, showing that the subject has been the object of extensive research aiming at improving the security, performance and resilience in maritime container transportation. Most of the studies focus on assessment of maritime risks by providing methods to reduce delay impact of this risk but just a few of them detailed research in risk types and risk class. In the last decade, risk classes are detailed by only 3 articles and just one of them detailed risk classes in multi-modal maritime supply chain. The authors in (Ho et al. 2015) addresses relevant problems to SCRM using approaches that fall within the AI spectrum. They propose a classification related to external, internal and problem-specific risk. The authors in (Wan 2018) presents an overview of the maritime container supply Chains by providing three levels of risk types of maritime container supply chain. To conclude the authors in (Vilko & Hallikas 2012) provides a holistic and systemic view of risk visibility and control in maritime supply chains by using simulation based on qualitative interview data of stakeholders involved in shipping industry in southern Finland and the Gulf of Finland. (Vilko & Hallikas 2012) show that connecting the delay impact probability distributions to the identified risk event probabilities permit to analyze maritime supply chain resilience. Nevertheless none of the studies have proposed risk typology which can permit to know what risk stakeholders should address first in order to improve their transport performance. In addition these proposed typologies don't permit to build a decision support tool in order to detect and mitigate risk in real-time.

### 5.1 Research implication

Multi-modal maritime supply chains are dynamic and become more and more complex (Vilko et al. 2019). Maritime Risk class identification is an essential step to provide a list of risks in order to help stakeholders involve in multi-modal supply chain manage them well (Wan 2018). Some studies like (Tang & Nurmayana 2011) (Ho et al. 2015) and (Abdel-Basset et al. 2019) have provided insights into risk management in general that permit supply chain managers to identify relevant risks in order to mitigate severe impacts. But just a few of them really focus on risks categorisation in multi-modal maritime supply chains according to their impacts, which would provide a better view of a management team's ability to control them (Vilko & Hallikas 2012). This

Risks	Det	Impacts			
		Delay	Financial	Quality	Environmental
<b>Physical Flow</b>					
Route deviation		Arrival time(CA, SH)	Extra charge(SH)	Lost of reputation(CA)	Carbon footprint (CA, SH)
Piracy		Lead time(SH)	Goods value(SH) Container value(CA)	Lost of reputation(CA)	X
Unexpected Door opening		X	Goods value(SH)	Lost of reputation(CA) Goods quality(SH)	X
Unexpected Temperature variation		X	Goods value(SH)	Lost of reputation(CA) Goods quality(SH)	X
Unexpected Humidity variation		X	Goods value(SH)	Lost of reputation(CA) Goods quality(SH)	X
Shocks		X	Container value(CA) Goods value(SH)	Lost of reputation(CA) Goods quality(SH)	X
Container damage	X	X	Container value(CA) Goods value(SH)	X	X
Good damage	X	Lead time(SH)	Goods value(SH)	Lost of reputation(CA) Goods quality(SH)	X
Container theft/ lost	X	Lead time(SH)	Container value(CA) Goods value(SH)	Lost of reputation And customers(CA)	X
Vehicle theft	X	Lead time(SH)	Vehicle value(CA) and Goods value(SH)	Lost of reputation And customers(CA)	X
Cargoes theft	X	Lead time(SH)	Goods value(SH)	Lost of reputation And customers(CA)	X
Long waiting time	X	Arrival time(CA, SH)	Extra charge(CA)	Lost of reputation(CA) Goods quality(SH)	X
Congestion	X	Arrival time(CA, SH)	Extra charge(CA)	Lost of reputation(CA) Extra cost(SH)	X
Bad Handling	X	X	Container value(CA) Goods value(SH)	Lost of reputation(CA) Goods quality(SH)	X
<b>Information Flow</b>					
Lack of visibility	X	Arrival time(CA)	Extra charge (SH, CA) Goods value(SH)	Lost of reputation And customers(CA)	Carbon footprint (SH, CA)
Lack of anticipation	X	Resource management(CA) Resource management(SH)	Extra charge (SH, CA)	Lost of reputation(CA)	Carbon footprint(CA)
Old technology	X	Data acquisition(CA)	Extra charge(CA, SH)	Lost of reputation(CA)	Carbon footprint(CA)
Lack of knowledge on product characteristics		X	Goods value(SH)	Lost of reputation(CA) Goods quality(SH)	X
Delay in transmission	X	Arrival time(CA) Uncertainty in planning(SH)	Extra charge(SH)	X	Carbon footprint(CA)
Lack of standardization		Insight production(SH)	X	X	Carbon footprint(CA)
Lack of analyze on past flows	X	X	Extra charge(CA)	Lost of reputation(CA)	Carbon footprint(CA)
<b>Context</b>					
Fire		Lead time(CA, SH)	Container value(CA) Goods value(SH)	Lost of reputation(CA) Goods quality(SH)	X
Unstable weather		Arrival time(CA, SH) Lead time(CA, SH)	Extra charge(CA)	Goods quality(SH)	X
Transport Strike	X	Lead time(CA, SH)	Extra charge(CA)	Lost of reputation(CA)	X
Political instability	x	Lead time(CA, SH)	Extra charge(CA) Good value(SH)	X	Carbon footprint(SH)
War	x	Lead time(CA, SH)	Extra charge(CA) Good value(SH)	X	X
Country policy	x	Lead time(CA, SH)	Extra cost Good value(SH)	X	X

Table 3 – Risk typology

research addresses the gap of maritime risks identification and classification by providing risk typology according to supply chain flow, their detectability and their impacts (Delay, Financial, Damage and environmental) in shipper and carrier activities. The results of this study contribute to risk management literature by giving a novel typology of risk in maritime supply chain. Our proposed typology presents relevant risks present in multi-modal maritime supply chain confirmed by a series of stakeholders involve in container multi-modal transportation interviews and a large review of the literature. This novel typology also present how risk events can affect carrier and shipper activities.

## 5.2 Discussion

The literature review shows that most of the studies in maritime supply chain management and supply chain management in general focus on assessing operational, environmental or demand risk class 6. Almost all of the studies focus on reducing occurrence probability of an hazardous events and the severity of the impacts of risk (Wan 2018). Our study provides an overview in risk identification of supply chain in order to help carrier and shipper involve in multi-modal maritime risk management. First, an analysis of risks typologies and risk classes present in risk management literature is provided, This showed that hazardous events could be classified into seven risks families. Then a selection of most relevant risks according to carrier and shipper was achieved with of help of qualitative interviews. Afterwards, while knowing that the impacts vary according to the actors of the supply chain, a study of these risk family in terms of detectability and potential impact was carried out according related to selected stakeholders involved in the shipping process. Analyzing the detectability and impacts of hazardous events is essential for multi-modal maritime supply chain because it permits to determine what risk events stakeholders can reactively and/or proactively address in order to allow the supply chain to be more safe and resilient. This study finds its limits in the fact that the proposed impacts are limited only to the carrier and shippers, in addition the study doesn't propose methods to quantify risk events occurrence and their impacts severity on multi-modal container transportation supply chain.

## 6 CONCLUSION AND FUTURE WORK

In this paper, we have reviewed recent literature relevant to Multi-modal Maritime Supply chains Risk Management. Risk classes, their impacts, and risk typologies have been investigated. Most of the literature focuses on mitigation on maritime risk affect in supply chain by providing quantitative and qualita-

tive technique and method to avoid severe impacts of maritime accidents and hazardous events. Research shows that risk events in maritime supply chain can be regrouped in seven risk families (supply risk, business risk, demand risk, operational risk, environmental risk, organizational risk and infrastructural risk). All these risk families are mostly time classed in three categories, external or internal, macro or micro typology and following supply chain flow (physical, information and financial flow) and their impacts on transportation supply chain can be categorized in four different types: delay impact, financial impact, quality impact and the environmental impact. This work indicates a larger number of articles in risk management in maritime transport area.

This study also provides an overview of maritime supply chain risk management by providing a new risk typology more adapted for carrier and shipper involved in maritime transport process. This risk typology indicates detectability and shows potential impacts for shipper and carrier involved in multi-modal maritime supply chain. To overcome the limitation of the current study we will propose in a future study a conceptual framework which integrate container real-time monitoring data and exogenous data, that can be used to build a decision support tools which permit to detect risk event and quantify in real-time risk impacts in multi-modal maritime supply chain. The future work will provide data-sets to be used or correlated to detect each hazardous events identified in proposed typology.

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