Logistics Research (2022) 15:4
DOI_10.23773/2022_4

Cargo Accumulation Risks in Maritime Supply Chains: A new perspective towards Risk Management for Theory, and Recommendations for the Insurance Industry and Cargo Shippers

Stephan L. K. Freichel[1]; Johannes K. Wörtge[1]; Arthur Haas[1]; Lars ter Veer[2]

Received: 30 June 2021 / Accepted: 25 May 2022 / Published online: 16 June 2022 ©
The Author(s) 2022 This article is published with Open Access at www.bvl.de/lore

ABSTRACT

Global supply chains are becoming increasingly complex with many players involved, reducing visibility and control of commodity flows. The majority of worldwide goods flows are distributed by sea, which means that ever greater vessels and ever greater ports play a central role in Supply Chain Management. Hence, increasingly large quantities of goods and hazardous substances accumulate stationary and mobile at these locations. The natural riskiness of maritime distribution is heightened since a large number of shipments are simultaneously determined by only one risk event. In this paper, the currently under-researched phenomenon of accumulation risk (AR) is investigated, using a qualitative-explorative research approach. Based on the relevant scientific and practical literature, AR is first defined and characterized against the background of Supply Chain Risk Management (SCRM). Subsequently, 23 interviews with a total of 34 experts from the insurance industry and various cargo-shipping industries were conducted and analyzed using qualitative content analysis (QCA). In this way, the current practices regarding AR handling of maritime insurers and cargo shippers were identified. Moreover, challenges hindering and opportunities enabling better risk identification, assessment, and management are explored. Lastly, an outline for future risk management and monitoring tool is established. Hereby, a theoretical contribution to research is made and grounded in the four phases of SCRM by adding a new perspective on maritime supply chain risk. Likewise, practitioners in the insurance industry and users of maritime distribution networks will find concrete recommendations on how to deal with AR.

KEYWORDS: Accumulation Risks · Supply Chain Risk Management · Global Supply Chains · Supply Chain Insurance

‘‘‘This article is part of a focus collection on ‘‘Supply Chain Analytics in the 2020s”.

✉ Stephan L. K. Freichel[1], Corresponding Author
stephan.freichel@th-koeln.de; +49 221 8275 2562

Johannes K. Wörtge[1]

Arthur Haas[1]

Lars ter Veer[2]

[1] TH Köln, Cologne University of Applied Sciences, Cologne, Germany

[2] Zurich Resilience Solutions, Frankfurt am Main, Germany

1. INTRODUCTION

“If companies should be insured for only one risk, it should be accumulation” (Pascal Dubois, Director General Insurance – CESAM)

Globalization and constant pressure for improvement in recent years led to increased complexity in global supply chains (SC). Companies worldwide develop and implement measures to realize shorter lead times, punctual deliveries, or optimized inventory levels [1]. High dependence on key countries and key partners, complex value chains, and a focus on efficiency are not only leading to cost advantages but also to SC vulnerability. Companies and Politics need to be aware of this, as we are living in the era of so-called “fat-tailed risks”. This means that situations with disastrous consequences – for instance wars, pandemics, floods, earthquakes, or blackouts – not only occur more frequently, but the situations themselves become also more extreme [2]. The combination of fragile SC with the increasing number and severity of extreme events is leading to increased risk for the global economy, as it depends on functioning SC. During the last few years, at least one out of 20 companies encountered a SC disruption of at least 100 million dollars [3]. Especially the corona crisis has revealed how vulnerable some SC are. The same applies to the war in Ukraine [4]. This

indicates both an increasing importance and a new approach to supply chain risk management (SCRM) as a whole, as risks frequently influence a company's business and need to be handled and understood to reduce their likelihood of occurrence and their potential impact [5, 6].

SCRM has been extensively addressed by academia [7–12]. Supply chain risk is defined as *"the likelihood and impact of unexpected macro and/or micro-level events or conditions that adversely influence any part of a supply chain leading to operational, tactical, or strategic level failures or irregularities"* [12]. SCRM, in terms of a phase model, deals with methods to identify these risks, evaluate their impact on SC, develop measures to deal with them, and establish end-to-end monitoring of potential sources and consequences of risk [13, 14]. The objectives of SCRM are, on the one hand, to reduce SC vulnerability, and on the other hand, to reduce the respective risk effect on SC functionality [15]. Extensively, but rarely uniformly, relevant SC risks have been identified and categorized in the literature [e.g. 7, 16–18], and risk identification methods have been proposed (e.g. AHP [19] or cause-and-effect diagrams [20]). Evidence on risk assessment methods is also available [e.g. 21, 22], often of an industry-specific nature. The management of risk through risk acceptance, risk avoidance, risk transfer, risk sharing, and risk mitigation is also a topic of research [e.g. 23–26]. Less explored is the issue of risk monitoring [11].

The risk of unforeseen events occurring is unavoidable, just as risk situations are piling up due to the development of global supply chains [27]. Despite approaches to identify, assess, manage and monitor risk, it is in the nature of complex systems, of which SC are a part, that it is almost impossible to eliminate all risks. Unforeseen situations will continue to occur in the future, making it increasingly important to establish resilient SC that will still function when such situations occur [3, 27]. These are often more costly than SC designed for efficiency, as additional capacity must be maintained, but such settings can increase supply chain performance [28]. Central to resilient SC is building capabilities to anticipate and overcome SC disruptions and reduce SC vulnerability [29]. This article will focus on a key risk of global SC that so far has received little attention: the accumulation risk in maritime transportation. We argue that the current marine SC configurations are inherently risky and the typical approaches of SCRM need to be reviewed and adjusted, especially against the background of their importance to the worlds' economy and the occurrence of fat-tailed risks.

Within the last 20 years, the value of transported goods tripled to over ten trillion dollars yearly, and over 90% of global trade volume is carried overseas, cumulating to over 11 billion tons in 2020 [1, 30]. The size of the ships used for this purpose, as well as the size of the ports entrusted with handling the goods, has been increasing continuously for years [31]. As a result, ever greater values of goods are accumulating at specific, stationary, and mobile geographical locations [32]. Maritime transport and the associated ports are particularly exposed to fat-tailed risks (e.g. earthquakes, tsunamis, floods, wars, etc.) while at the same time they are of central importance for the functionality of many up-and downstream supply chain segments [33]. Despite the relevance for the global economy and the susceptibility to risk, and while the consequences associated with accumulation risk have already been impressively revealed on several occasions in the past [3, 28–30, 32–34], accumulation control in the transport sector is still difficult to implement, although methods have steadily evolved, and complex probabilistic catastrophe models already exist to simulate numerous potential events [35].

In the first place, cargo owners are substantially affected in the event of supply chain disruptions. Concerning current inventory-reducing practices such as just-in-time (JIT) or just-in-sequence (JIS), a potential disruption within the SC significantly impacts downstream parties in terms of material shortages, leading to production delays or stops, causing severe financial losses [1]. Moreover, share price losses, loss of market share, or declines in investor confidence are potential consequences [36]. However, the insurance industry is considerably affected by such events, as they have to cover a large number of their policyholder's losses [34]. For insurers, maritime transport is a particular concern, as it is often not clear to them what different insurance risks accumulate in one place. While stationary risks, e.g. at ports, can be localized and assessed quite precisely, mobile risk identification, assessment, management, and monitoring is difficult to achieve. Even though the marine transport routes are known in theory, the tracking accuracy regarding the vessels is often low in practice. The uncertainties due to constant movement also apply to ports due to the quick transshipment speed of goods. This lack of transparency and the specific requirements of marine insurance makes it almost impossible to properly model loss potentials. There is only a limited number of accumulation control products on the market. The association of german insurers (*Gesamtverband der Deutschen Versicherungswirtschaft* (GDV)) offers a so-called *Kumul Informations Service* (KIS), which insurers can use to geocode their worldwide risks, taking into account the geographical location, the risk sum, and the exposure to natural hazards [37]. An important factor when dealing with mobile risks is the use of technology, enabling companies to track and monitor shipments, which helps to prevent upcoming losses. While sensors can automatically monitor the status of the shipment in the containers, big data and analytics offer the ability to assess cargo ARs and enable the creation of data-based modeling [38]. This, however, requires collaboration between the SC partners.

As shown, there is a wide range of literature concerning various SCRM approaches. Research specifically related to identifying and evaluating cargo- and value accumulation in maritime SC is scarce, despite the mentioned developments and possible consequences such events can cause. In the course of this paper, we aim to give theory and practice a deeper look into this matter. Based on the four-phase model of SCRM and a comprehensive exploratory study, the phenomenon of AR is defined, characterized, and inserted into the general framework of SCRM. The focus of this paper is particularly on the practices and methods used by SC partners to deal with the specific risk. Risk monitoring approaches, which are currently and will be of increasing relevance in the future, are also addressed. In particular, the following research questions are answered:

RQ I: "How can 'Accumulation Risk' in marine SC be characterized against the background of SCRM?"

RQ II: "How and why do different SC-Partners deal with the 'Accumulation Risk' in marine SC?"

RQ III: "How can the risks of Accumulation in marine SC be managed in the future?"

The findings developed here are of value to researchers and practitioners. The former can use them, for example, as a basis to substantiate current SCRM frameworks or to develop specific risk models for maritime SC. The latter can use the results to discuss the specific risk with their respective SC partners and, based on this, develop new methods for risk assessment, risk management, and risk monitoring.

The rest of this paper is structured as follows: The second chapter provides the theoretical background of cargo AR by characterizing cargo accumulation situations and the factors leading to them. Against the background of SCRM, the specifics of AR in marine SCs are outlined. In the subsequent chapter, the methodology of the research approach, as well as the data collection and data analysis procedure are explained. The evaluation of these results takes place in the following fourth Chapter. In Chapter five a discussion of the results takes place. Theoretical and managerial implications are derived. A brief conclusion including the limitations of this paper and further research possibilities is given.

2. THEORETICAL BACKGROUND

2.1. Cargo Accumulation Situations

Accumulation situations occur in global SC whenever several consignments are concentrated at a common location for a certain period. This bundling of goods is one of the most important elements for efficient supply chain management, as it allows pooling effects to be exploited in all logistics processes. Compared with the individual processing of shipments, this significantly reduces logistics costs and at the same time permits high service levels.

First, a distinction can be made between stationary and mobile accumulation situations. Stationary situations occur for instance in factories, warehouses, office buildings, oilrigs, or residential buildings. In contrast, mobile accumulation is not tied to one place, hence referring to goods in transit. However, this does not imply that goods are constantly moving since they are sometimes stored in one place for 30-60 days or longer [39]. A characteristic that defines accumulation situations in maritime supply chains is a partial ignorance about what exactly is accumulated [34, 35], as such knowledge is not of high relevance for most supply chain partners. The consideration of the negative side effects of cargo accumulation is only important for those entities that also bear the negative consequences. Up to now, these have been insurance companies in particular, which, in the dynamic network of global supply chains, are losing transparency about the respective concentration points and the insurance sums allocated there. However, the disadvantages of cargo accumulation at a few key points have also become apparent for entire economies in recent years, when these structures failed and entire SC and the associated businesses collapsed downstream. More figuratively, the dangerous side effects of accumulation became apparent when explosive or flammable goods

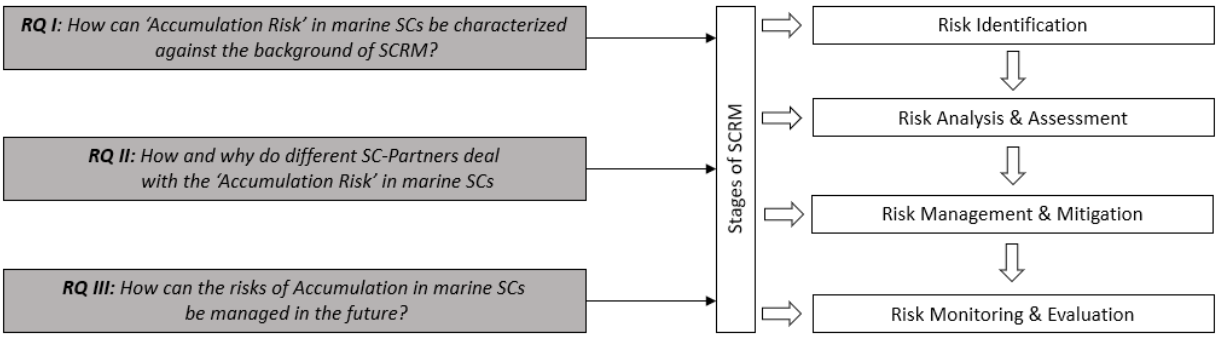

Figure 1: Research questions in connection to the four phases of SCRM, Source: Own figure

were involved, such as in the Tianjin disaster [34]. We argue in this article that the aspect of cargo accumulation in maritime SCRM has so far been given too little importance against the background of increasing accumulation intensity in some places that are particularly affected by increasing risk situations of a "fat-tailed risk" world.

In this study, cargo accumulation is understood as the spatial and temporary aggregation or concentration of shipped cargo. Especially four major causes lead to them:

- ***Increasing transport capacities:*** The steadily growing container vessels pose a significant threat in terms of cargo AR. Besides the increasing volume of trade, particularly the growing demand for more efficient transportation is responsible for the development of container ships. The HMM Algeciras is currently the largest container ship globally, with a capacity of 23,964 TEU (20-foot standard container) [40]. In comparison, the largest container vessel's capacity in 1968 was approximately 1,500 TEU, in 2002 almost 9,000 TEU, and in 2013 about 18,000 TEU.
- ***Scheduling:*** Particularly in the seaport industry, several schedule changes occur in terms of vessel arrival time due to numerous factors such as weather, delays caused by previous stops, or capacity utilization. Operations within the seaport depend on vessels' arrival time and need to be planned a few weeks in advance. Depending on the customer's pickup or onward transportation, the containers are either temporarily stored or stowed in the yard. As stated in a report published by McKinsey, 48% of container ship enters the port with a delay of more than 12 hours, increasing fuel consumption and unbalanced port capacities [41]. Beyond that, schedule changes complicate terminal operations concerning the allocation of berths, quay cranes, yard storage plans as well as the disposition of internal tractors. Particularly, the Covid-19 pandemic led to a significant increase in cargo accumulation in port terminals, warehouses, or distribution centers as supply and demand fluctuated widely worldwide. The container ships' berthing process took extensively longer than planned, leading to canceled sailings and re-routing of vessels, accompanied by shipping container shortage [42]. Generally, the duration of container vessels remaining in ports has doubled since 2019, increasing the risk of a potential cargo accumulation since cargo converges on one spot over a longer period [43]
- ***Bottlenecks:*** Another aspect, linked to the scheduling topic, are bottlenecks in global SC. If they are blocked, huge amounts of cargo are waiting to be further processed. A severe example is the Suez Canal blockade early in 2021, one of the most important trade routes, handling at least ten percent of global seaborne trade due to a grounded container ship. As a result, numerous container ships are jammed, waiting to pass the canal or have to take the longer route around Africa. Besides devastating consequences such as the disruption of global SC and impacts on oil prices and shipping rates [44], this scenario also poses an enormous AR since cargo's spatial and temporal concentration by waiting ships is exceptionally high. In the event of a storm or heavy sea, the effects could be severe due to the large volume of goods.
- ***National holidays:*** In addition, national holidays like the Chinese New Year (CNY) also have an impact on the accumulation of goods. Even though CNY only lasts about one week, many factories close several days in advance and afterward to ensure that workers have enough time to get home to their families. Thus, approximately two to four weeks, manufacturers, suppliers, and partners cease their operations. Besides, ports and customs only operate with a limited number of workers to ensure the handling of critical and perishable cargo [45]. As a result, public holidays lead at specific periods of the year to a disruption of port operations. Either vessels are waiting to enter the port, or berthing operations persist, the movement of cargo slows down and significantly increases the probability of an AR since larger volumes of goods converge on one spot over a longer period [46].

2.2. Characterizing and Defining AR in the context of SCRM

In practice and academia, the need for adequate SCRM methods is unanimously emphasized, especially against the background of global value chains, increasing cost pressure, higher customer demands on logistics performance, and growing competition [6]. Hauser states that SCRM enables companies to manage their SC more effectively and gain a strategic advantage in a competitive marketplace [47]. The Process of SCRM can be divided into four interconnected steps: a) risk identification, b) risk analysis and assessment, c) risk management and mitigation, and d) risk monitoring and evaluation [48]. In summary, SCRM is about identifying all potential risks that can determine a SC and specifying their probability of occurrence and their impact. If necessary, measures are then derived from this and implemented, as well as continuous monitoring is to be established. Traditionally, SCRM is a company-based approach that relates to the SC of a single company. So-called "Joint SCRM" approaches also refer to a single supply chain, although all partners involved in this chain operate joint risk management through information exchange and risk-sharing mechanisms [49, 50].

Cargo accumulation risks are different, as they result from the temporary combination of SC sections of one or several companies. An AR indexation consists of three dimensions: a) the accumulation severity, indicating the strength of accumulated consignments

for the respective party, b) the likelihood of occurrence of a risk situation and c) the potential impact on the respective party, in case the risk situation emerges at a location with accumulated consignments. This characterization is deliberately broad to be applicable to different use cases. It includes individual companies whose relevant shipments are accumulated in one place – often without their knowledge – as well as shipping companies, insurance companies, or governments. It indicates that an adjusted view of SCRM in the four phases mentioned is required. However, since one entity must ultimately be responsible for risk identification and assessment, as well as for coordinating necessary measures between the various companies and supply chain partners, the first step is to determine the perspective from which such an approach is to be defined. Since the actual financial consequences are bundled with insurers, they have a special interest in establishing risk management. Moreover, they have a holistic perspective on this phenomenon, as they are often the only entity with – more or less – complete transparency about the goods accumulated in one location. Accordingly, the remainder of the study will primarily take their perspective. The specifics of AR in the context of SCRM are characterized based on the four phases mentioned above:

- ***Risk identification:*** Within the first step of the SCRM process, the objective is to identify all relevant risks which could potentially affect a SC in order to be able to decide whether a further assessment of risk is recommendable or not. The identification of potential threats and vulnerabilities within the SC and the environment depends on a regular examination of early indicators and requires a comprehensive approach [51]. The literature lists a variety of such risk types, just as many different structuring grids have been established [7, 52–58]. A typical delineation is into operational and disruptive factors, the former resulting from planning and processes (e.g. uncertain customer demands, uncertain supply, equipment malfunctions, etc.) and the latter from natural or man-made disasters (e.g. earthquakes, wars, floods, etc.) [7, 56]. This identification of potential risk factors is retained as the first dimension when considering AR but is complemented by the identification of accumulation situations. The goal must be the precise indication of accumulation severity for different entities. If there is no accumulation, there is no need for AR-specific risk management and a traditional SCRM approach is sufficient for the respective entity.
- ***Risk analysis and assessment:*** Risk assessment in traditional SCRM includes two main issues according to several authors, the determination of the probability of occurrence as well as the estimation of potential consequences and losses [51–53, 56, 59]. Thus, the main objective in this stage is to obtain sufficient information about the identified risks, their risk drivers as well as key vulnerabilities within the SC. Available models typically focus on analyzing specific risks such as macro risks from natural disasters [e.g. 60], demand risks [e.g. 61, 62], or supply risks [e.g. 63, 64] [see 12 for a comprehensive overview]. From an AR perspective, the question to be evaluated within this process stage is how high the probability of a risk occurrence is at the geographical location at which a high accumulation severity also arises at the same time. This accumulation severity is entity-specific, so different results can emerge for different stakeholders. This also determines the analysis of the individual impact. Hence, the result of this phase is a three-dimensional AR indication based on the dimensions "risk probability", "accumulation severity" and "impact", which indicates a different AR result, depending on the perspective taken.
- ***Risk management and mitigation:*** This stage aims to use the previously gathered data and experiences to develop and implement measures to reduce or eliminate the probability of occurrence and potential risk impacts. On the one hand, it requires mitigation strategies in advance to avoid the occurrence of risk events. On the other hand, contingency plans need to be executed after an event [51]. The "traditional" SCRM literature indicates, in addition to risk type-specific approaches [e.g. 65, 66], some general approaches to risk avoidance, such as building resilient SC [15, 67], better information sharing among SC partners [68], and overall stronger collaboration with partners [69]. For AR, other measures are needed both to prevent potentially dangerous accumulation situations in advance and, if an accumulation situation has already materialized, to resolve it quickly before risk can arise at the site.
- ***Risk monitoring and evaluation:*** Once adequate measures have been implemented to reduce or eliminate risks, the next step is to monitor and evaluate the actions taken to achieve continuous improvement. Regardless of whether the implementations taken were successful or not, the risks still need to be examined to check the effectiveness of developed measures and modify them if necessary. After all, constant changes within the environment occur frequently and require companies' dynamic and flexibility to comply with new situations [51]. These changes can occur within the network, customer requirements, technology, competitors, or partner strategies and require continuous monitoring and updating [70]. Risk monitoring and evaluation apply analogously to AR-specific SCRM.

What has been outlined so far highlights the benefits, but also the issues, of cargo accumulation situations and

the key drivers of increasing accumulation in maritime SC. Against this background, we define AR as ***'the likelihood and impact of a specific risk situation, in which one or more supply chain entities are severely affected by the emergence of a risk situation due to their direct or indirect responsibility for or dependency of several consignments concentrated at one location'***. Based on theoretical derivations, the first research question can thus be considered answered by defining and characterizing AR in the context of SCRM. AR is different from typical SCR and requires adaptation of the typical SCRM process in all four phases. However, the current state of the literature does not provide an answer as to how and why AR-specific SCRM is carried out in practice. An explorative study should provide initial insights.

3. METHODOLOGY

Since the research topic of AR in maritime SC has received little attention in the academic literature, an exploratory qualitative research design is adopted. Data collection and data analysis are qualitative and interpretive, which is particularly useful when the research field is open so far and corresponding hypotheses and theories have to be built up first, not tested [71, 72]. Since the relevant literature has so far not provided sufficient answers as to how different SC entities deal with the AR and why they act the way they do, an explorative qualitative approach is particularly useful. Empirical data was collected and structured interpretatively to gain insight into the reality of the research object [73]. For this purpose, experts acting in this field were interviewed regarding their experiences and insights into the field. Interviewing experts is an appropriate method of data collection in Logistics and Supply Chain Research, as this can provide deep insights into the reality of practice [74, 75].

To ensure the quality of the research, specific quality criteria need to be accomplished. Whereas the quality criteria of quantitative research are in general objectivity, reliability, and validity, the quality criteria in qualitative research are not clearly defined [72, 73, 76]. One criterion is the theory-driven approach, meaning that the own analysis is linked to the existing theoretical knowledge about the research object [77]. By providing the theoretical background in chapter two, which was taken into account by setting up the interview guideline and interpreting the results, this criterion is met in this paper.

A second quality criterion is the researcher's neutrality and openness to new findings, which means that in terms of conducting expert interviews, the researcher always has to be open to information and evaluations that do not correspond to the previously collected perceptions related to the topic examined. Thus, the interviewee must also have the opportunity to contribute to these evaluations. Besides, neutrality requires that the expert interviews do not serve to obtain confirmation of one's existing assumptions [77]. This criterion was fulfilled in this study since semi-structured interviews were developed that enable the respondents to speak freely as the topic is covered rather limited in academic literature, and no specific assumptions were made [78].

Specifically related to the execution of a QCA, there are further quality criteria taken into account. According to Mayring and Fenzl, an excerpt-based review is sufficient since the objective is not to achieve a complete agreement, especially in terms of an inductive category development and its interpretative components [79]. Therefore, they mention *intracoder agreement* and *intercoder agreement* as the main quality criteria. *Intracoder agreement* describes the re-evaluation of the results after the analysis has been completed without looking at the previously assigned categorizations. Thus, the stability of a procedure and hence the reliability can be examined. This criterion was accomplished in this study by revisiting and analyzing the interview transcripts and ensuring consistency with the first review results. To achieve *Intercoder agreement*, two researchers coded the data material independent of each other. Deviations from each other were discussed in the research group [79].

3.1. Data collection

Using interviews is a common method to collect data and get an overview of experts' understanding and interests concerning the respective topic [71]. Therefore, 23 interviews with a total of 34 experts were held. Among the interviewees were experts from the manufacturing industry owning and shipping cargo (=cargo owners), the transport insurance sector, and independent SC or marine insurance experts. Among the cargo owners are experts from different industries, reaching from multinational industrial engineering conglomerates to globally operating companies that manufacture automobiles, industrial gases, chocolate, precision machinery, tobacco, and medical technology equipment. The insurance experts are experienced in the industrial insurance sector and are either active in marine underwriting or risk management. Cargo owners and insurance experts account for the majority of the interviews. The third group of experts are either active in the SC sector or belong to insurance industry associations.

An overview is presented in Table 1. All 23 interviews were conducted digitally via video conference. Due to the scarcely explored insights concerning cargo accumulation, semi-structured interviews were adopted in order to allow the interviewee to talk freely and receive more in-depth information [78]. The interview guide was based on open and closed questions, and the Likert-scale was considered as a scale instrument. While open questions serve as a good opportunity to explore rather limited reviewed topics, rating questions help to obtain more specifications on a particular subject area [77].

Industry	Role	Interview number
Insurance	Marine Underwriting	2, 4, 5, 8, 11, 13, 14
Insurance	Risk Management	7, 9, 10
Cargo owner/Shipper	Risk Management/Insurance	3, 12, 15, 21, 23
Cargo owner/Shipper	Supply Chain/Logistics Management	16, 17, 18, 19, 22
Experts	Supply Chain Consultant	1
Experts	Marine Insurance	6, 20

Table 1: Categorization of interview partners, Source: Own table

The interview questionnaire contains 15 questions and was created and pre-tested in association with three persons from the field. An abbreviated version of the interview guideline is provided in Appendix I. The questions were designed to gain further insights into the topic of cargo accumulation. Three questionnaires were created, all with the same content. However, due to the three different industry sectors of the respondents, some questions were slightly adapted. In general, the questionnaire is structured in four main parts: a) the current situation in handling AR, b) the challenges that arise in this context, c) the evaluation of specific risk factors, and d) the required measures and solutions for a successful accumulation control.

The increasing transport volumes and the orientation of transport operators towards efficiency inevitably lead to the concentration of goods on ships, ports, terminals, etc. This factor itself cannot be avoided and is not initially severe. However, previous events such as Yantian, Tianjin, Beirut, or Apus One have shown the dimensions that a single event can cause. Accordingly, the SC responsible must be aware of their specific flow of goods and the associated cargo accumulation to make appropriate decisions and take appropriate actions. In preparation for the individual interviews, the interviewees were given information in which the researchers understanding of risks, as outlined in chapter two, was explained.

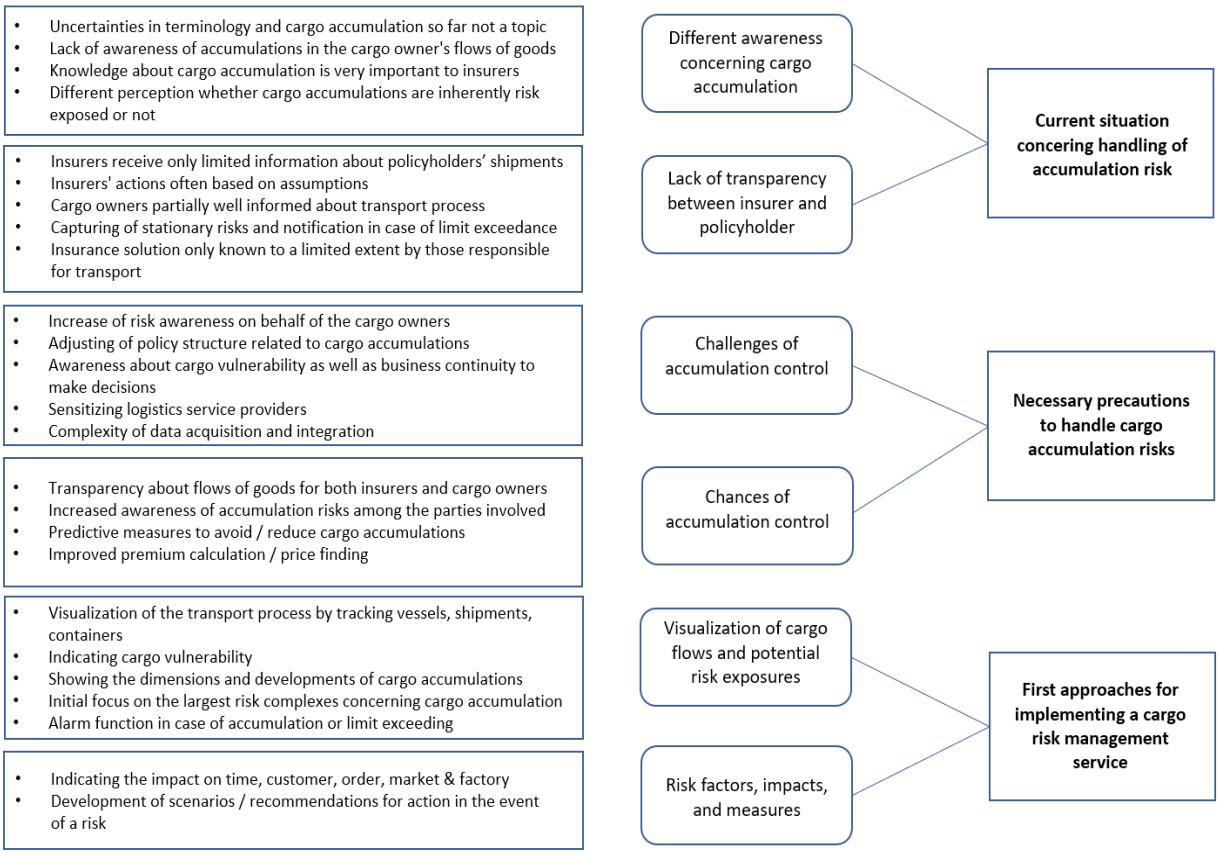

Figure 2: First order concepts, second order themes and aggregated dimensions; Source: Own figure

3.2. Data analysis

An interpretative research approach, inspired by Qualitative Content Analysis (QCA) [73, 77] was conducted for data analysis. We therefore first transcribed the interviews and cleaned the data from unnecessary text passages. Then the interview material was paraphrased and summarized to the core statements. The QCA software MAXQDA was utilized to code the paraphrases and further aggregate the findings into interconnected first-order concepts [74, 80]. The researchers then had the task to formulate more theoretical and conceptual second-order themes, further generalizing and heightening the level of abstraction. In a third step, the concepts were grouped into three aggregated dimensions.

A total of 25 similarities were created from the interviews, representing the first level of abstraction. Searching for further connections led to the development of a higher level of abstraction, including six second-order themes. These connections finally resulted in the creation of three dimensions that build the framework structure. While the contents of the first two dimensions are suitable to answer the second research question, the contents of the third dimension provide answers to the third research question. Figure 2 represents the created category system, which forms the basis for presenting the empirical findings gathered [80].

4. EMPIRICAL FINDINGS

The developed category system, which emerged from the QCA, forms the guideline for describing the results in the following chapter. First, a description of the current situation is given, specifically how the different actors see and evaluate the phenomenon of AR. The second part highlights the main challenges and opportunities in dealing with AR. Finally, a first approach to implement an AR management system is presented.

4.1. Current situation concerning the handling of accumulation risk

In the analysis conducted, it became clear that two aspects, in particular, determine the current management of AR: First, a different view of the phenomenon of AR among the SC partners involved, and second, a low degree of transparency between insurers and the policyholders.

4.1.1. Different awareness concerning cargo accumulation

The knowledge about cargo accumulation situations partially varies among the respondents, just as the perception of the associated risks. While the importance of knowing about accumulation situations was rated as very important (2,4,5,7,8,9,11,13) and important (10,14) by the insurers, the statements on behalf of the cargo owners range from very important (3,12,18) to unimportant (17). For the insurers, it is essential to be aware of their policyholders' flow of goods and the respective accumulations occurring during the transport of their shipments. In this regard, they receive none or only limited information (2,4,5,7,8,9,10,11,13,14). Cargo owners partially have some uncertainties about the term "accumulation". Moreover, they indicate that AR has not been an issue yet in their respective supply chains (17,22). Others, however, even though the concept of cargo AR was also new, have rated the importance of its management as important after receiving the definition of cargo AR (16,18). Regarding the measures that should be implemented in case of cargo accumulation without risk exposure and with risk exposure, two different main perspectives could be identified. Most insurers make no distinction concerning the risk exposure in case of an accumulation, meaning that every cargo accumulation itself is already perceived as risk exposed without other influences (6,9,10,11,20). Cargo Owners differentiate measures for risk exposure, saying that an accumulation without risk exposure does not represent a risk and does not require any action (3,15,17,23).

Against the backdrop of the three-dimensional framework concept of AR, which was presented in chapter 2, there are clear differences regarding the company-specific risk definition. While insurers focus on the accumulation severity, cargo owners concentrate more on the likelihood of a risk situation occurring. This is particularly the case because the impact on the party is considered different in each case.

4.1.2. Lack of transparency between insurer and policyholder

Marine insurers state that they receive limited information from the policyholder and criticize the lack of transparency about cargo flows and potential accumulations. They predominantly receive information on stationary risks. The quality of the received information concerning cargo transport partially depends on the policyholder's profile or the product (1,2,4,5,6,7,8,9,10,11,13,14). Once the goods start moving, most insurers claim to be completely blind about the transport routes and vessels utilized, destinations, ports, involved service providers, or the actual cargo and its current location (2,8,9,13). Accordingly, the insurance experts state that the collection of possible transport information is sometimes very vague, and therefore the determination of premiums and loss ratios is often based on assumptions (5,7,13,20).

In turn, some of the cargo owners claim to have very precise knowledge concerning the end-to-end transport process from initial departure to final delivery. They know the routes, the number of shipments per ship, the ports, the service provider involved, destinations, and in some cases, arrival times (3,17,19,21,23). In some cases, certain contracts have been settled with service providers to know about the logistics (sub-) service

providers used, and a regular exchange of information takes place in this regard (3,19,21,22). In contrast, the companies' insurance solutions, specifically concerning event limits, are only known in a few cases by those in charge of handling the transport and bookings. While some are very familiar with the insurance solution and have a recurring exchange with insurers and insurance brokers (3,12,22), others have hardly any information about it at hand (17,18,23). Four cargo owner experts indicate that their company has a general or global policy or All-Risk insurance coverage (15,16,19,22).

Regarding the current situation of cargo AR understanding, it becomes clear that there are large differences between the marine SC partners. Insurers consider this risk to be very relevant but receive little information about the mobile risk points within the supply chain. Policyholders, on the other hand, consider this risk less relevant but in many cases have relevant data to reveal the AR. However, this data is rarely shared with insurers.

4.2. Necessary precautions to handle cargo accumulation risks

Having outlined the different views of the marine SC partners towards AR, it is necessary to consider how the management of these risks is conducted by the respective partners. The analysis of the qualitative data indicates two overarching concepts in this regard. First, there is a strong need to address specific challenges to reduce AR. Second, based on this, specific measures can be implemented to avoid AR, establish fitting SCRM and gain advantages from such procedures.

4.2.1. Challenges of accumulation control

The challenge most frequently mentioned by insurers and insurance experts in dealing with AR is the increase of awareness on behalf of the cargo owners. The respondents argue that too little attention is given to AR. Dealing with AR requires consideration in strategic risk management decisions and needs to be implemented and considered as a severe risk within a companies' SC environment (1,2,6,7,8,9,10,11,14,20). However, raising awareness within a company's SC is also seen as necessary by the cargo owners themselves (3,16,18,19). In this context, due to the size of some companies and their diverse product portfolio, cargo owners face the challenge of internal transparency. While individual divisions are aware of their respective cargo flows, there is a lack of transparency about whether other divisions within the same company have goods in the same port or on the same ship at the same time (3,12,15,23).

Moreover, the awareness of LSP towards cargo AR needs to be addressed. Carriers have the booking data, and besides knowing who ordered something on a ship, they have information about the type, number, and value of shipments. Hence, they are ultimately the SC partners with the highest data access and are therefore a key party for reducing accumulations (2,7,11,13,). A cargo owner, for instance, who operates an active accumulation control and tries to spread the risk by splitting his shipments and using several carriers does not profit from risk reduction if the carrier loads the shipments on the same aircraft to heighten transport efficiency (7). Thus, it was mentioned as critical to sensitize LSP like carriers, freight forwarders, shipping companies, or port operators regarding AR. Insurers, for their part of managing AR, need to adjust the policy structure to claim more transparency on behalf of the cargo-owning company (5,6,11). The insurance experts also consider it their responsibility to provide more support to policyholders regarding the issue of accumulation and to drive awareness (2,4,5,6,8,9,10).

Another challenge to tackle on both sides is a comprehensive knowledge of business continuity (BC) and cargo vulnerability in terms of AR. Almost all respondents rated the knowledge about a products' vulnerability in case of an accumulation as important or very important, hence vulnerability is evaluated as a severe risk. The views regarding BC in the event of AR differ. Insurers' opinions range from very important to unimportant, depending on the type of coverage. If only the cargo is insured, BC is not important in the event of a loss (2,8,13,14), while it becomes important or very important, if the business interruption is also insured in addition to a marine policy (6,7,9,11). For cargo owners, on the other hand, BC is a critical factor. Depending on the company's size and the product, whether it is a finished and/or turnkey product or materials that are necessary for production, most of the respondents are likely to find that an accumulation loss will also affect a company's BC (6,12,15,18,19,21,22,23). As products are often delivered JIT, any accumulated losses have a significant impact on BC. Further, companies are forced to reduce their safety stocks, so in most cases, the affected materials have to be reordered (12,15,22,23). Due to some companies' size and diversity, it is unlikely that an accumulation loss will affect the BC of the entire company, but rather individual business lines. The issue of BC is particularly critical when several key products for different business segments are accumulated, as the continuity of different divisions is determined (16,18).

Another challenge for transport insurers is the complexity of integrating and visualizing their entire portfolio when monitoring cargo accumulations of their clients. Given the number of policyholders, it is hardly possible to provide a comprehensive accumulation control over their entire portfolio (2,5,8,9,10,13). One suggestion is to focus initially on a limited number of customers, ideally those that generate the most revenue (1,5). Another problem is continuously maintaining and updating data in a potential accumulation control tool. The required data should ideally update automatically utilizing a central system since implementing data manually could evolve the aspect of human error and may lead to incorrect results (3,4,12,20,21).

4.2.2. Chances of accumulation control

The most commonly mentioned aspect in addressing the management of AR is transparency (1,2,3,4,5,6,7, 9,11,12,14,16,20,23). While the increase of transparency towards the cargo flow is a critical challenge for both cargo owners and insurers, it simultaneously creates the opportunity to gain insights into the flow of goods for both parties. This facilitates the identification and evaluation of risk exposures and consequently states chances to derive profound decisions and actions (1,2, 3,4,5,6,7,9,11,12,16,20,23). By tackling the challenge of awareness among the SC partners, transparency may increase, as the partners start to share more information about the flow of goods. This may state an opportunity to implement a common cargo AR management approach, engaging risk prevention and mitigation, hence leading to heightened BC and delivery capabilities.

Concerning dealing with AR, the focus must be on preventing risk situations. If the bundling of goods has already occurred, it is difficult to unbundle it again, since the bundling point is often mobile. In addition, the redistribution of stationary accumulation is costly and time-consuming. If such a case has occurred, the insurance company should be contacted, as well as the event limit should be checked and, if possible and necessary, adjusted (2,4,7,12). Predictive measures to avoid AR at an early stage are the most relevant approach for insurers and policyholders. Several are stated by the interviewees:

- ***Splitting of shipments:*** Among the measures presented to avoid or reduce cargo accumulation, the splitting of shipments is, despite the additional costs this implies, the most appropriate measure perceived by both insurers and cargo owners and is most likely to be implemented (2, 3, 5, 6, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18, 20, 21, 22). This has already been recommended by insurers and actively implemented in case of a limit exceedance (4,8,9,10,11,17,20,21). On the other hand, this method depends on the goods being transported and is therefore not practicable for all companies.
- ***Redundant SC-setting:*** Another factor perceived as important is the redundant SC set-up, i.e., using multiple sources, routes, or service providers. Although this concept is not feasible for all cargo owners at once and must be planned thoroughly in advance, it is an essential factor for the respondents in avoiding AR (1,4,6,9,11,13,14,15,17,19,20).
- Delaying cargo flows: Experts are divided on the issue of speeding up or slowing down the flow of goods. For the majority of cargo owners slowing down the flow of goods is not an option, as goods have to be stored longer than planned, which in turn creates accumulation, and companies that produce JIT cannot accept any delays (2,4,6,8,12,13,15,19,23). In contrast, one insurer stated that delaying goods' flow was already actively recommended and ultimately carried out. Here, goods were stored longer within a warehouse rather than having to be stored on a transport mean at the border crossings and the ferries, as the goods are more likely to be exposed to hazards there than in the warehouse (10). If an increase in working capital is generally met with criticism, the situation after Covid has changed slightly. Thus, increasing inventory is not always perceived as unfavorable (16).
- ***Accelerating cargo flow:*** The problem with accelerating the cargo flow is that subsequent processes are not always designed to be accelerated, which can lead to further difficulties. As soon as transport is speeded up, for example, cargo is ordered onto a ship earlier than initially planned, the responsible LSPs in the port of destination or the end consumer need to adapt their processes to avoid complications (6,8,10,12,15,17,19,23). Conversely, acceleration has already been actively practiced by taking goods out of ports or hubs earlier than planned in the event of potential hazards. Another example is the acceleration in the context of Covid to maintain production by moving out more items in a short period due to a potential lockdown (1,3,5,6,13,21).
- ***Deviating Routing:*** Deviating routing also has advantages as well as disadvantages. A frequently mentioned cause for deviation from the route or port is congestion. Congestion in the ports has the consequence that goods remain longer than planned on berthing ships or ports and significantly increases the risk of accumulation (5,21,22). The risk of theft on specific routes is also a reason to change the route (6,17).

All measures have their advantages and disadvantages, and the most appropriate measure depends on the situation (6,11). Ultimately, concerning AR, it must be understood that the biggest incentive factor for joint risk management by all parties is SC costs. Thus, this is also where the greatest opportunity for joint implementation lies. Insurers can achieve an improved premium calculation based on actual and predictable risk exposures, and cargo owners can reduce potential interruptions within the SC and thus save costs.

At this point, the second research question can be evaluated as answered. There is a difference in the assessment of AR between insurers and policyholders, which strongly depends on the individual impact on the company. Insurers typically bear the higher risk in this regard, as they are more often financially responsible for accumulated consignments. Hence, they concentrate on accumulation severity from a financial perspective, independent of the respective probability of a risk event occurring. In the case of the cargo owners, they assess the risk as not more relevant as "normal" risk cases, since they only bear their share of the accumulated risk. This view changes, when cargo owners understand

the potential impact on BC, especially against the backdrop that several individual risks of the cargo owners can be accumulated without them noticing. Accumulation severity in the view of cargo owners is hence measured in terms of how important the accumulated consignments as a whole are for BC. Just a few accumulated turnkey products may interrupt the business, while not being expensive in financial terms. This underlines the different perspectives on AR and the necessity of a broad definition and a holistic understanding of the phenomenon. The linchpin of dealing with AR is increased attention to the issue by all SC partners and, as a result, greater implementation of cross-actor transparency. In addition, especially predictive measures may be used to avoid AR in the first place. Particular interests shape AR and must be overcome so that all SC partners benefit from lower risks. Ultimately, this must be worthwhile in terms of costs.

4.3. First approaches for implementing a cargo risk management service

It became clear that a joint approach by all SC partners is needed to deal with AR. The experts outlined the possibility of establishing a risk management service for dealing with AR in the future. The cornerstones of such a service are, on the one hand, the visualization of the flow of goods to indicate potential risks. On the other hand the presentation of the respective risk consequences.

4.3.1. Visualization of cargo flows and potential risk exposures

According to insurers and policyholders, the most important aspect of a risk management service is the visualization of the flow of goods, for which they are having responsibility or from which their businesses are dependent. This should be carried out by showing the flows on a world map (2,3,5,9,12,13,15,17,21,22). Besides tracking shipments and vessels' locations, such a service needs to display company-specific accumulation severity (2,3,6,7,11,18). In this context, the temporal accumulation development was addressed, i.e., how differently intense or weak accumulations are over time and when the concentration begins to decrease again. Aside from tracking shipments, a risk management tool should include geocoding of stationary risks such as warehouses (8,14,15). Many respondents consider it important to have an alarm function in case of cargo accumulations or limit exceedances so that the user has the opportunity to take action at an early stage (1,5,6,9,19,20,23). Insurers are interested in visualizing their customer portfolio with the help of the tool to be able to track the flow of goods and to consult with customers at an early stage to develop strategies to mitigate (5,8,11,13). Therefore, the knowledge about the sum insured is also relevant for them.

Opinions differ on tracking the flow of goods in real-time. While some respondents from both parties argue that real-time is not essential for them (11,15), others are convinced that real-time data would add significant value, as it is critical to know where potential cargo accumulations are at any given moment to act promptly. This would essentially contribute to the company's SCRM (11,14,18,20).

4.3.2. Risk factors, impacts, and measures

In addition to the visualization of the cargo flows, the prediction of risks and the risk exposures related to the cargo is an often-mentioned aspect on behalf of both parties (2,3,4,6,7,8,9,11,16,18,20). Rating the risk complexes that pose the greatest threat to respondents in terms of cargo accumulations, natural hazards and weather rank first for almost all interviewees (1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,23). The next most frequently mentioned risks are geopolitical developments such as strikes in Chile or border closures (1,2,4,8,12,14,15,16,17,18,19,21,), the condition of transport means due to the increasing shipment volume and partly outdated ships or unrestored containers (3,5,6,7,8,9,10,11,12,16,20,22). A further aspect is the influences on the schedule, which are of importance for perishable or time-critical goods (2,4,5,8,9,12,13,17,21,22,23).

Apart from only indicating the flow of goods, the degree of cargo accumulations and potential risk factors, illustrating the impacts of a possible accumulation loss is essential to the respondents (1,2,4,5,7,9,16,17,19,21,23). On the one hand, indicating the effects on time and order, and on the other hand, highlighting the impacts on specific factories and corresponding markets if a factory cannot run regularly (17). In case of a cargo accumulation, it is not only important to receive a notification about the occurrence, but also to depict scenarios and indicate possible recommendations for actions, as many are not aware of what measures need to be taken and do not have any risk management in place (4,7,9,16,17).

With regard to a common approach to dealing with AR in the future, the experts are still not very specific in their statements. Both insurers and policyholders require a risk management tool. Such a tool should first visualize the flow of goods and accumulation points worldwide, and also show the intensity of the accumulation points over time. An alarm function is also proposed so that measures can be discussed and initiated at an early stage. In addition, such a tool should indicate the risk factors at the respective accumulation locations concerning their probability of occurrence, present the consequences of a risk occurrence, and automatically suggest possible measures to deal with the risk. This also answers the third research question.

5. DISCUSSION

5.1. General discussion of the results

While trends such as rising trade volumes, increasing transport capacities, or the growing accumulation potential in ports underline the importance of AR, this topic is only marginally addressed in academic literature. A few reports have been published from the insurance industry concerning the threat of accumulations risks [1, 32, 81]. Nevertheless, to date, none of the research examining SC risks refers to AR in specific. In order to obtain more insights into this topic, AR as a concept was first theoretically defined and characterized against the backdrop of the four-stage framework of SCRM. Moreover, interviews with experts from the insurance and cargo shipping industry were carried out. Thereby, valuable information about the *identification, assessment, management, and evaluation* of cargo AR were gathered. Accordingly, this paper states a contribution to the academic literature on SCRM by introducing the risk of accumulation in global maritime freight and examining it from the perspective of cargo owners and insurance companies.

Although the number of articles written specifically about cargo AR is limited to consultancy and sector-specific reports [1, 3, 36, 41], the interviews revealed its significance. However, there a strong differences between insurers and cargo owners in terms of knowledge, understanding, and risk assessment. While insurers see any form of accumulated consignments in their responsibility as a potentially risky situation, most cargo owners are not even aware of it, do not consider it as a significant risk, or have problems with the terminology. This lack of awareness by cargo owners also becomes evident in the elaboration of the conceptual framework, as this risk is not considered within the context of SCRM until now. One of the apparent reasons why the importance of AR is rated higher on the side of insurers is that they are significantly affected by paying for their policyholders' incurred losses in the event of an accumulation loss. Another possible reason for the lack of awareness on behalf of cargo owners results from the policy structure. According to several insurers, the policy structure is set up too generically and requires barely any reporting obligations from policyholders. Although cargo owners have to accept a limit per loss or means of transport, further precautions when creating the policies are required. Insurers are already partially addressing this problem by attempting to determine the risk exposures in their policyholders' SC to be able to consider these when calculating premiums.

We were able to show that cargo owners should also have an increased interest in the issue of AR. Insurers assess AR predominantly from a financial perspective – they bear the financial responsibility for a large number of consignments accumulated at certain locations. The potential financial loss of the consignments is their respective measure for accumulation severity. This is different for cargo owners, as the pure financial sum of accumulated consignments is comparably low. However, an accumulated loss can significantly determine BC, if several turnkey products are jointly affected. In this context, the problem of silo mentality [82, 83] within larger companies emerged since individual business segments are usually very well informed about their respective cargo flow but might not be aware of cargo from other business segments within the same company. Consequently, this lack of awareness increases the danger of accumulation if several business segments of the same company book their cargo on one ship without considering that other units may have cargo on the same vessel. That is what is special about AR – under the broad definition; different perspectives can and must be combined. By adding the dimension "Accumulation Severity" to the understanding of SCR, exactly this is made possible and offers further studies a basis to also integrate other actor viewpoints.

The main causes of AR are particular interests of individual supply chain actors and a lack of information sharing among them, as has been frequently pointed out in the relevant literature on SCRM [49, 84]. This leads to a focus on individual shipments rather than the overall system of all commodity flows. There is simply a lack of transparency when goods are starting to move. In this context, several insurers stated that they lack information about goods in transit and can only make assumptions regarding their location. Due to the lack of transparency, the shipments and corresponding cargo values a policyholder ultimately has on one transport mean are unknown to the insurer. Considering the large number of policyholders in an insurer's portfolio, several of them may be transporting goods on one vessel at the same time. Even if they comply with the maximum per means of transport, the large number of insured risks on a ship poses a significant threat for primary transport insurers and reinsurers, as in the event of a damage/loss, high costs arise. In this regard, insurers were very surprised about how many policyholders ended up transporting goods on the same ship. A severe scenario would be the sinking of a container ship or the collision of two mega-ships. In this case, many of the large transport insurers would be severely affected, as they insure both the goods and the ship. Although this has not happened yet, such a scenario may occur in the future.

Considering these facts against the background of the mentioned SCRM steps, the identification and the assessment of AR need severe adjustments, taking into account the risk of accumulated cargo. Moreover, practical risk management approaches are needed. This requires a player who takes a holistic view of the flow of goods. Insurance companies, in particular, seem to be suited to establish and operate a holistic AR management system. For doing so, they are dependent on detailed and updated information about

their policyholder‘s transports such as route, time, type of cargo, or parties involved. What is surprising is that this information is already available. Most cargo owners have very precise knowledge about their flow of goods, including the routes, the departure and arrival times, as well as the service providers. Regarding the service providers, several cargo owners have concluded framework agreements and have therefore known their service providers for several years. In contrast, the results from the interviews revealed that logistics and supply chain managers or those who are ultimately responsible for the number of shipments booked onto a transport mean have only limited knowledge about the potential risk accumulation can state in general, as well as their company’s event limit in particular. As a result, they might tend to concentrate cargo volume on one carrier in case of sufficient transport capacity without considering the potential consequences of an accumulation or the allowed event limit. These information deficits on both sides give rise to high risks for each party, which can be offset by greater transparency. In this way, risks, as well as costs, can be reduced for both sides.

5.2. Theoretical contribution

This paper offers four theoretical contributions to the literature, which can be structured and explicated into the aspects of risk identification, risk analysis, risk management, and risk monitoring using the phase model of SCRM [48, 57].

Regarding risk identification, the term and concept of AR are defined and its novelty in relation to the general SCRM literature was highlighted. The latter initially focuses on the identification of external, disruptive risk factors that can determine an individual SC [7, 17, 56, 85]. These include, among others, earthquakes or flood disasters. The literature shows that marine supply chains, in particular, can be determined by these factors, as they are often geographically located in areas, typically affected by natural disasters. The importance of ports for global supply chains is also emphasized [33, 86, 87]. Furthermore, the general SCRM literature indicates the operational, endogenous risks in supply chain management, which can occur, for example, due to supply and demand uncertainties [10, 16, 51]. This paper extends the SCR identification with the new perspective of Accumulation Severity, which allows a more precise, AR-encompassing indication of the respective impact on different SC entities. The identified AR is rooted in the supply chain itself and describes the problem when larger quantities of goods are bundled at a stationary or mobile location over a longer period. These cases have increased in recent years due to ever-larger ships, increasing global trade, shipment schedules, national holidays, and bottlenecks in the supply chain. Accumulation situations increase on the one hand, as do external risks, which then encounter the AR. We showed in general, that the overall risk of global supply chains is increasing for both insurers and cargo owners.

In terms of risk analysis, our findings first indicate that the overall risk of global supply chains is increasing and that risk assessment requires a more comprehensive, multi-actor perspective [48, 51, 56]. This is particularly important for insurance companies, as they bear the majority of the financial risk. Such companies, in particular, must increasingly seek to obtain more comprehensive information on the commodity flows of their policyholders to assess the risk exposure. Nevertheless, cargo owners must also become aware of the AR and therefore adopt a cross-company perspective. The potential for several key products from multiple divisions to accumulate unnoticed is real and can greatly determine the company’s BC. With this in mind, information sharing between both parties is relevant as ultimately the information is available that allows for better risk analysis. If these are used, both parties can benefit not only from risk reduction but also from cost reduction.

In general, risk management builds on the data gathered in the risk analysis phase to develop and implement strategies for risk avoidance or reduction [48]. We were able to show that, with regard to AR, preventive measures are necessary to avoid accumulation. Subsequent unbundling rarely makes sense against the background of operational and cost consequences. The linchpin of measures regarding AR is awareness of accumulation, especially among policyholders, as well as data transparency concerning the flow of goods between insurers and insured parties [67, 68, 70]. Based on this, tailor-made risk avoidance measures can be implemented. Of particular relevance is the splitting of shipments and the establishment of redundant supply chain segments [3, 15]. However, this is only feasible if downstream service providers are also informed about these practices, as otherwise there is a danger that separated shipments will be accumulated again after all. Other measures can include accelerating or decelerating the flow of goods, or using alternative routes. However, these three measures must always be examined for their usefulness against the background of the respective situation, as they can also lead to accumulation.

Finally, concerning risk monitoring, we have made a prospective proposal on how a continuous risk-monitoring tool for AR could look like. This should be operated by one actor, due to the highest impact we suggest insurance companies to share the tool with their policyholders. First, a visualization of commodity flows and bundling points should be shown, the latter also including the time component of bundling intensity. The tool should also have an alarm function that warns of risks at an early stage so that adequate measures to avoid risks can be initiated in time. Furthermore, such an instrument shall show the most important risk factors and their probability of occurrence at the respective accumulation nodes of the supply chain, as well as the potential financial and continuity-related consequences in the event of a risk occurrence.

5.3. Managerial Implications

In this section, the focus is on the actions required to manage AR in the future considering the *identification, assessment, mitigation,* and *control* of AR. Parts of the recommendations for action have already been briefly addressed throughout this paper but will be emphasized more comprehensively in the following.

Raise awareness and establish a common risk understanding: The most important recommendation that can be made for both insurers and policyholders is that there must be a common understanding of the relevance of AR. Insurers need to actively approach cargo owners and enlighten them about the importance of AR. Cargo owners should be educated about the misleading idea of being insured against any damage. Considering the mentioned consequences of an accumulation loss and the consequential financial loss aspect, this type of risk should be taken seriously. Cargo owners are not covered against all consequences such as share price losses or declines in investor confidence and often enough not against business continuity disruptions. Given the current circumstances, such as the increasing competitive pressure, decreasing stock levels, growing demand for efficiency, and increasing natural hazards, the awareness of all involved SC parties should be raised since one defect within a SC could affect several parties. Accordingly, the cargo owner's suppliers have to be sensitized as well in terms of AR. Therefore, the idea of transporting as many goods as possible at once to exploit capacity and be efficient in this regard must be thoroughly considered and restricted against the background of the risks associated with accumulation. Therefore, a common understanding of AR needs to be created among the involved parties, as well as this needs to be integrated into risk management systems.

Increase transparency and collaboration between the SC partners: Although the AR is recognizable and has often led to high losses in the past, it is surprising that little is being done about it. Especially since the necessary data to assess and manage the risk are available. Accordingly, it is urgently recommended to increase data transparency and collaboration between SC partners. As indicated in the literature [67, 68, 70], a close exchange between insurers and cargo owners is required. Cargo owners need to share crucial shipment data with their insurers. Specifically, insurers need to know the types of products the cargo owner distributes and their respective values, the number of products usually shipped to determine the maximum, the transport times, the routes, and the service providers. The exchange of such information would enable the insurer to get a comprehensive picture of the policyholders' SC structure and thus to identify, assess and manage the risks in general and the AR in specific. As this allows insurers to adequately calculate the premiums in a transparent and comprehensible way, awareness on this behalf is raised, and policyholders benefit from better risk coverage and/or cheaper premiums. An important aspect is the adjustment of the current policy structures, as they are too broadly designed and thus specify no obligation to report on behalf of the policyholder. Consequently, the comfort level should be lowered, and relatively strict limits should be applied to the policy, meaning defining certain limits per event per year. To increase this limit, the policyholder needs to be more transparent with the insurer.

Set up preventive measures to avoid cargo AR: Since retrospective measures to dissolve AR are difficult to realize operationally and are cost-intensive, the focus must be on preventive risk avoidance strategies. Concerning transportation design and the reduction of cargo concentration, the splitting of shipments and a redundant SC setup are the most important and feasible actions. A redundant SC setup cannot be implemented short term, but the idea behind it is to introduce a certain degree of diversification into the design of routes, service providers, or sources to reduce the development of cargo accumulations. Splitting shipments and the resulting additional costs are also an imaginable solution for many cargo owners. However, this measure would only be feasible if the affected party is informed about an accumulation at an early stage and can contact the responsible service providers. Accordingly, this would also be advantageous for insurers due to the lower concentration of values per transport mean. Nonetheless, an implementation also depends on the LSPs. Consequently, it is also essential to sensitize them in terms of AR and to work out appropriate solutions to ensure profit for all parties.

Develop holistic risk management and monitoring tool: The visualization of the commodity flows using a world map proves to be an essential instrument for risk monitoring and risk management in the future. Especially the mapping of routes as well as the tracking of vessels and shipments add value. Considering BC and cargo vulnerability, the number of shipments per vessel, the product type, and the condition during transport is also of relevance when making decisions. However, a successful implementation is only possible if the parties involved are willing to make their transport details available on a common platform. Beyond simply tracking the flow of goods to identify potential accumulations, the respondents need to indicate the risk exposures they could face. Due to a large number of various risks, an initial approach would be to consider only the risk complexes rated as most severe. Here, it requires the implementation of historical and current events, which have to be geocoded and linked with the current locations of shipments. As soon as AR or a limit exceedance is indicated, an alarm appears to be an important function to take measures at an early stage. Specific measures depend on the individual situation, hence, possible scenarios and measures to avoid or reduce the impact have to be presented, which need to be individually adapted to the respective user. As this requires additional information to determine

the cargo vulnerability and the BC threat, the more transparent the users are, the more comprehensive risk advice can be offered. Big data analytics and artificial intelligence approaches can be used over time to make ever-better suggestions on how to deal with the risks being faced. Since insurers are much more affected by AR than individual cargo owners, it seems reasonable that a holistic risk management tool is also established by them. They not only benefit from better decisions but can also commercialize this service. This may be an interesting business model.

6. CONCLUSION, LIMITATIONS, AND FURTHER AREAS OF RESEARCH

While there is plenty of research concerning SCRM, the risk of cargo accumulation receives limited consideration and represents a research gap despite the events that occurred in the past have caused significant damage. Therefore, increased emphasis needs to be placed on identifying, assessing, managing, and finally mitigating those risks, as the trade volume and the demand for efficiency will continue to increase as well as the number of natural hazards, which is not done concretely in the academic literature. This paper defines and characterizes the phenomenon of AR and identifies its unique features relative to other SCRM literature sources (=RQ I). Further, the current handling of cargo AR is detailed from the perspective of insurers and policyholders. Existing challenges and opportunities in the four phases of SCRM regarding this risk type are highlighted (=RQ II). Moreover, the characteristics of a future risk management and monitoring tool are outlined (=RQ III). This culminates in four specific theoretical contributions and four detailed recommendations for managerial action.

The present results are associated with some limitations, which state chances for future research. Methodologically, using a qualitative research approach is associated with limited generalizability and objectivity. Even though the survey revealed consistent conclusions from experts from different sectors, the results should not be generalized due to the limited number of respondents. Based on our findings, hypotheses can be formed which can be subjected to an objective and generally valid test in the course of a quantitative study. Of particular interest might be the correlation between increased information transparency between stakeholders and the reduction of risk. However, this first requires the integration of the specific AR into existing risk analysis models, which allows further possible research approaches. Due to the constant uncertainties in dealing with risks, the usage of fuzzy models finds increasing attention in understanding and assessing SC risks, especially in combination with the concept of FMEA [88–93]. Hence, it is suggested that further research investigates the consideration of fuzzy logic when developing a risk management approach to assess cargo AR. Further, this research does not consider other involved stakeholders' insights than the insurance industry and cargo shipping companies. In the course of our investigation, it became apparent that LSPs in particular have access to comprehensive information. The extent to which this information can be integrated and the potential it offers seems worthy of investigation. Finally, it appears that a holistic risk management tool has a high benefit for both insurance companies and cargo owners. Although we were able to show some elements of a possible tool, the concrete conceptualization remains open. This seems to be a very interesting area not only for research but especially in terms of a business model for insurers.

LITERATURE

1. Lund S, Manyika J, Woetzel J, et al (2020) Risk, resilience, and rebalancing in global value chains
2. Flyvbjerg B (2020) The law of regression to the tail: How to survive Covid-19, the climate crisis, and other disasters. Environ Sci Policy 114:614–618. https://doi.org/10.1016/j.envsci.2020.08.013
3. Alicke K, Barriball E, Lund S, Swan D (2020) Is your supply chain risk blind-or risk resilient? McKinsey Co 1–6
4. O'Donnell J (2022) Ukraine war, sanctions will extend supply chain disruption. TechTaget
5. BCI, Zurich (2019) Supply Chain Resilience Report 2019
6. Daultani Y, Kumar S, Vaidya OS, Tiwari MK (2015) A supply chain network equilibrium model for operational and opportunism risk mitigation. Int J Prod Res 53:5685–5715. https://doi.org/10.1080/00207543.2015.1056325
7. Tang CS (2006) Perspectives in supply chain risk management. Int J Prod Econ 103:451–488. https://doi.org/10.1016/j.ijpe.2005.12.006
8. Rao S, Goldsby TJ (2009) Supply chain risks: a review and typology. Int J Logist Manag 20:97–123. https://doi.org/10.1108/09574090910954864
9. Tang O, Nurmaya Musa S (2011) Identifying risk issues and research advancements in supply chain risk management. Int J Prod Econ 133:25–34. https://doi.org/10.1016/j.ijpe.2010.06.013
10. Sodhi MS, Tang CS (2012) Managing Supply Chain Risk. Springer US, Boston, MA
11. Fan Y, Stevenson M (2018) A review of supply chain risk management: definition, theory, and research agenda. Int J Phys Distrib Logist Manag 48:205–230. https://doi.org/10.1108/IJPDLM-01-2017-0043
12. Gurtu A, Johny J (2021) Supply chain risk management: Literature review. Risks 9:1–16. https://doi.org/10.3390/risks9010016
13. Zsidisin * GA, Melnyk SA, Ragatz GL (2005) An institutional theory perspective of business continuity planning for purchasing and supply

management. Int J Prod Res 43:3401–3420. https://doi.org/10.1080/00207540500095613
14. Hachicha W, Elmsalmi M (2014) An integrated approach based-structural modeling for risk prioritization in supply network management. J Risk Res 17:1301–1324. https://doi.org/10.1080/13669877.2013.841734
15. Jüttner U, Maklan S (2011) Supply chain resilience in the global financial crisis: An empirical study. Supply Chain Manag 16:246–259. https://doi.org/10.1108/13598541111139062
16. Jüttner U, Peck H, Christopher M (2003) Supply chain risk management: outlining an agenda for future research. Int J Logist Res Appl 6:197–210. https://doi.org/10.1080/1367556031000162701 7
17. Olson DL, Dash Wu D (2010) A review of enterprise risk management in supply chain. Kybernetes 39:694–706. https://doi.org/10.1108/03684921011043198
18. Samvedi A, Jain V, Chan FTS (2012) An integrated approach for machine tool selection using fuzzy analytical hierarchy process and grey relational analysis. Int J Prod Res 50:3211–3221. https://doi.org/10.1080/00207543.2011.560906
19. Gaudenzi B, Borghesi A (2006) Managing risks in the supply chain using the AHP method. Int J Logist Manag 17:114–136. https://doi.org/10.1108/09574090610663464
20. Lin Y, Zhou L (2011) The impacts of product design changes on supply chain risk: a case study. Int J Phys Distrib Logist Manag 41:162–186. https://doi.org/10.1108/09600031111118549
21. Nepal B, Yadav OP (2015) Bayesian belief network-based framework for sourcing risk analysis during supplier selection. Int J Prod Res 53:6114–6135. https://doi.org/10.1080/00207543.2015.1027011
22. Blackhurst J V., Scheibe KP, Johnson DJ (2008) Supplier risk assessment and monitoring for the automotive industry. Int J Phys Distrib Logist Manag 38:143–165. https://doi.org/10.1108/09600030810861215
23. Aqlan F, Lam SS (2015) Supply chain risk modelling and mitigation. Int J Prod Res 53:5640–5656. https://doi.org/10.1080/00207543.2015.1047975
24. Diabat A, Govindan K, Panicker V V. (2012) Supply chain risk management and its mitigation in a food industry. Int J Prod Res 50:3039–3050. https://doi.org/10.1080/00207543.2011.588619
25. Buzacott JA, Steve Peng H (2012) Contract design for risk sharing partnerships in manufacturing. Eur J Oper Res 218:656–666. https://doi.org/10.1016/j.ejor.2011.12.008
26. Chopra S, Sodhi MS (2004) Managing Risk To Avoid Supply-Chain Breakdown. MIT Sloan Manag Rev 46:53–61
27. Aggarwal R, Bohinc J (2012) Black swans and supply chain strategic necessity. J Transp Secur 5:39–49. https://doi.org/10.1007/s12198-011-0080-5
28. Pettit TJ, Croxton KL, Fiksel J (2013) Ensuring supply chain resilience: Development and implementation of an assessment tool. J Bus Logist 34:46–76. https://doi.org/10.1111/jbl.12009
29. Pettit TJ, Fiksel J, Croxton KL (2010) ENSURING SUPPLY CHAIN RESILIENCE: DEVELOPMENT OF A CONCEPTUAL FRAMEWORK. J Bus Logist 31:1–21. https://doi.org/10.1002/j.2158-1592.2010.tb00125.x
30. UNCTAD (2020) Review of Maritime Transport 2020. New York
31. Tran NK, Haasis H-D (2015) An empirical study of fleet expansion and growth of ship size in container liner shipping. Int J Prod Econ 159:241–253. https://doi.org/10.1016/j.ijpe.2014.09.016
32. MunichRe (2013) Avoiding accumulation risks
33. Gou X, Lam JSL (2019) Risk analysis of marine cargoes and major port disruptions. Marit Econ Logist 21:497–523. https://doi.org/10.1057/s41278-018-0110-3
34. MunichRe (2016) Explosive Mischung
35. MunichRE (2016) Modellierung von Transportrisiken
36. Allianz Global Corporate & Specialty AG (2012) Managing disruptions: supply chain risk: an insurer's perspective
37. GDV (2021) KIS Einführung – Transport Informations Service. https://www.tis-gdv.de/tis/kis/einfuehrung-html/. Accessed 3 Dec 2021
38. Banerjee K, Ray P (2019) How Insurers Can Deal With Risk Accumulation – Wipro. https://www.wipro.com/insurance/how-insurers-can-avoid-and-alleviate-risk-accumulation/. Accessed 3 Dec 2021
39. Herbrich M (1992) Kumulkontrolle. Gabler, Wiesbaden
40. Pietsch A (2020) Even a bit bigger: Container ships are growing and growing | logistik aktuell. https://logistik-aktuell.com/2020/07/30/container-ships-are-growing/. Accessed 3 Dec 2021
41. Stone M, Saxon S (2017) Container shipping : The next 50 years
42. AGCS (2020) Marine claims trends 2018. https://www.agcs.allianz.com/news-and-insights/expert-risk-articles/global-claims-review-2018-marine-claims-trends.html. Accessed 3 Dec 2021
43. The Maritime Executive (2021) Time Containerships Spent Waiting for Berths Doubled in Two Years. https://www.maritime-executive.com/article/time-containerships-spent-waiting-for-berths-doubled-in-two-years. Accessed 3 Dec 2021

44. Sheppard D, Dempsey H, Saleh H (2021) Suez Canal remains blocked after huge container ship runs aground. Financ. Times
45. Howells R (2019) The Impact Of Chinese New Year On The Global Supply Chain. https://www.forbes.com/sites/sap/2019/01/25/the-impact-of-chinese-new-year-on-the-global-supply-chain/?sh=3977727849ca. Accessed 3 Dec 2021
46. Nze IC, Onyemechi C (2018) Port congestion determinants and impacts on logistics and supply chain network of five African ports. J Sustain Dev Transp Logist 3:70–82. https://doi.org/10.14254/jsdtl.2018.3-1.7
47. Hauser LM (2003) Risk-Adjusted Supply Chain Management. Supply Chain Manag Rev 7:64–71
48. Tummala R, Schoenherr T (2011) Assessing and managing risks using the Supply Chain Risk Management Process (SCRMP). Supply Chain Manag 16:474–483. https://doi.org/10.1108/13598541111171165
49. Li G, Fan H, Lee PKC, Cheng TCE (2015) Joint supply chain risk management: An agency and collaboration perspective. Int J Prod Econ 164:83–94. https://doi.org/10.1016/j.ijpe.2015.02.021
50. Jüttner U (2005) Supply chain risk management: Understanding the business requirements from a practitioner perspective. Int J Logist Manag 16:120–141. https://doi.org/10.1108/09574090510617385
51. Kern D, Moser R, Hartmann E, Moder M (2012) Supply risk management: Model development and empirical analysis. Int J Phys Distrib Logist Manag 42:60–82. https://doi.org/10.1108/09600031211202472
52. Harland C, Brenchley R, Walker H (2003) Risk in supply networks. J Purch Supply Manag 9:51–62. https://doi.org/10.1016/S1478-4092(03)00004-9
53. Manuj I, Mentzer JT (2008) Global supply chain risk management strategies. Int J Phys Distrib Logist Manag 38:192–223. https://doi.org/10.1108/09600030810866986
54. Chen J, Sohal AS, Prajogo DI (2013) Supply chain operational risk mitigation: A collaborative approach. Int J Prod Res 51:2186–2199. https://doi.org/10.1080/00207543.2012.727490
55. Kern D, Moser R, Hartmann E, Moder M (2012) Supply risk management: model development and empirical analysis. Int J Phys Distrib Logist Manag 42:60–82. https://doi.org/10.1108/09600031211202472
56. Kleindorfer PR, Saad GH (2005) Managing Disruption Risks in Supply Chains. Prod Oper Manag 14:53–68. https://doi.org/10.1111/j.1937-5956.2005.tb00009.x
57. Ho W, Zheng T, Yildiz H, Talluri S (2015) Supply chain risk management: A literature review. Int J Prod Res 53:5031–5069. https://doi.org/10.1080/00207543.2015.1030467
58. Baryannis G, Validi S, Dani S, Antoniou G (2019) Supply chain risk management and artificial intelligence: state of the art and future research directions. Int J Prod Res 57:2179–2202. https://doi.org/10.1080/00207543.2018.1530476
59. Ritchie B, Brindley C (2009) Effective Management of Supply Chains: Risks and Performance. In: Wu T, Blackhurst J (eds) Managing Supply Chain Risk and Vulnerability: Tools and Methods for Supply Chain Decision Makers. Springer London, London, pp 9–28
60. Ji G, Zhu C (2012) A Study on Emergency Supply Chain and Risk Based on Urgent Relief Service in Disasters. Syst Eng Procedia 5:313–325. https://doi.org/10.1016/j.sepro.2012.04.049
61. Ballou RH, Burnetas A (2003) PLANNING MULTIPLE LOCATION INVENTORIES. J Bus Logist 24:65–89. https://doi.org/10.1002/j.2158-1592.2003.tb00046.x
62. Talluri S, Cetin K, Gardner AJ (2004) Integrating demand and supply variability into safety stock evaluations. Int J Phys Distrib Logist Manag 34:62–69. https://doi.org/10.1108/09600030410515682
63. Talluri S, Narasimhan R, Nair A (2006) Vendor performance with supply risk: A chance-constrained DEA approach. Int J Prod Econ 100:212–222. https://doi.org/10.1016/j.ijpe.2004.11.012
64. Chaudhuri A, Mohanty BK, Singh KN (2013) Supply chain risk assessment during new product development: a group decision making approach using numeric and linguistic data. Int J Prod Res 51:2790–2804. https://doi.org/10.1080/00207543.2012.654922
65. Berger PD, Gerstenfeld A, Zeng AZ (2004) How many suppliers are best? A decision-analysis approach. Omega 32:9–15. https://doi.org/10.1016/j.omega.2003.09.001
66. Guo Z, Fang F, Whinston AB (2006) Supply chain information sharing in a macro prediction market. Decis Support Syst 42:1944–1958. https://doi.org/10.1016/j.dss.2006.05.003
67. Singh NP, Singh S (2019) Building supply chain risk resilience: Role of big data analytics in supply chain disruption mitigation. Benchmarking 26:2318–2342. https://doi.org/10.1108/BIJ-10-2018-0346
68. Nishat Faisal M, Banwet DK, Shankar R (2006) Supply chain risk mitigation: modeling the enablers. Bus Process Manag J 12:535–552. https://doi.org/10.1108/14637150610678113
69. Lavastre O, Gunasekaran A, Spalanzani A (2012) Supply chain risk management in French companies. Decis Support Syst 52:828–838. https://doi.org/10.1016/j.dss.2011.11.017

70. Hallikas J, Karvonen I, Pulkkinen U, et al (2004) Risk management processes in supplier networks. Int J Prod Econ 90:47–58. https://doi.org/10.1016/j.ijpe.2004.02.007
71. Creswell JW, Creswell JD (2018) Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, 5th ed. SAGE Publications, Los Angeles
72. Yin RK (2018) Case Study Research and Applications; Design and Methods, 6th ed. SAGE Publications, Thousand Oaks, California
73. Schreier M (2012) Qualitative Content Analysis in Practice. SAGE Publications, Los Angeles, et al.
74. Trautrims A, Grant DB, Cunliffe AL, Wong C (2012) Using the "documentary method" to analyse qualitative data in logistics research. Int J Phys Distrib Logist Manag 42:828–842. https://doi.org/10.1108/09600031211269776
75. Maanen J Van (1979) The Fact of Fiction in Organizational Ethnography. Adm Sci Q 24:539. https://doi.org/10.2307/2392360
76. Schreier M (2015) Qualitative Content Analysis. In: Flick U (ed) The SAGE Handbook of Qualitative Data Analysis. SAGE Publications, London ua., pp 170–183
77. Miles MB, Huberman AM (1999) Qualitative Data Analysis: An Expanded Sourcebook, 2nd ed. SAGE Publications, Thousand Oaks, California
78. Lindlof TR, Taylor BC (2011) Qualitative Communication Research Methods, 3rd ed. SAGE Publications, Los Angeles, et al.
79. Mayring P, Fenzl T (2019) Qualitative Inhaltsanalyse. In: Baur N, Blasius J (eds) Handbuch Methoden der empirischen Sozialforschung. Springer Fachmedien Wiesbaden, Wiesbaden, pp 633–648
80. Gioia DA, Corley KG, Hamilton AL (2014) Seeking Qualitative Rigor in Inductive Research. Organ Res Methods 16:15–31. https://doi.org/10.1177/1094428112452151
81. MunichRE (2013) Kumulrisiken geschickt umschiffen. https://www.munichre.com/topics-online/de/mobility-and-transport/transportation-of-cargo/avoidance-accumulation-risks-marine-transportation.html. Accessed 3 Dec 2021
82. Mangan J, Lalwani C, Butcher T, Javadpour R (2011) Global Logistics and Supply Chain Management, 2nd ed. John Wiley & Sons, Chichester
83. Bowersox DJ, Closs DJ, Cooper MB, Bowersox JC (2013) Supply Chain Logistics Management, 4th ed. McGraw-Hill, New York
84. Chen J, Sohal AS, Prajogo DI (2016) Supply risk mitigation: a multi-theoretical perspective. Prod Plan Control 27:853–863. https://doi.org/10.1080/09537287.2016.1147620
85. Craighead CW, Blackhurst J, Rungtusanatham MJ, Handfield RB (2007) The Severity of Supply Chain Disruptions: Design Characteristics and Mitigation Capabilities. Decis Sci 38:131–156. https://doi.org/10.1111/j.1540-5915.2007.00151.x
86. Berle Ø, Asbjørnslett BE, Rice JB (2011) Formal Vulnerability Assessment of a maritime transportation system. Reliab Eng Syst Saf 96:696–705. https://doi.org/10.1016/j.ress.2010.12.011
87. Goerlandt F, Montewka J (2015) Maritime transportation risk analysis: Review and analysis in light of some foundational issues. Reliab Eng Syst Saf 138:115–134. https://doi.org/10.1016/j.ress.2015.01.025
88. Ghadge A, Fang X, Dani S, Antony J (2017) Supply chain risk assessment approach for process quality risks. Int J Qual Reliab Manag 34:940–954. https://doi.org/10.1108/IJQRM-01-2015-0010
89. Wan C, Yan X, Zhang D, et al (2019) An advanced fuzzy Bayesian-based FMEA approach for assessing maritime supply chain risks. Transp Res Part E Logist Transp Rev 125:222–240. https://doi.org/10.1016/j.tre.2019.03.011
90. Liu H-C, Liu L, Liu N, Mao L-X (2012) Risk evaluation in failure mode and effects analysis with extended VIKOR method under fuzzy environment. Expert Syst Appl 39:12926–12934. https://doi.org/10.1016/j.eswa.2012.05.031
91. Renjith VR, Jose kalathil M, Kumar PH, Madhavan D (2018) Fuzzy FMECA (failure mode effect and criticality analysis) of LNG storage facility. J Loss Prev Process Ind 56:537–547. https://doi.org/10.1016/j.jlp.2018.01.002
92. Mangla SK, Luthra S, Jakhar S (2018) Benchmarking the risk assessment in green supply chain using fuzzy approach to FMEA. Benchmarking An Int J 25:2660–2687. https://doi.org/10.1108/BIJ-04-2017-0074
93. Fattahi R, Tavakkoli-Moghaddam R, Khalilzadeh M, et al (2020) A novel FMEA model based on fuzzy multiple-criteria decision-making methods for risk assessment. J Enterp Inf Manag 33:881–904. https://doi.org/10.1108/JEIM-09-2019-0282

APPENDIX I – ABBREVIATED VERSION OF THE INTERVIEW GUIDELINE

Current situation

- How important is it for you to be aware of accumulation and potential or actual risk exposures?
- What do you know about cargo accumulations in the flow of goods in the company's/policyholder's value chain?
- Have you already implemented measures to prevent cargo-/value accumulation?

Challenges / Chances & required measures

- What should change in your opinion concerning handling / approaching cargo accumulation risks?
- What actions would you take if you get notified of a possible accumulation with/without risk exposure?
- Which measures would you adopt/prefer in order to prevent accumulation/exposure?

Evaluation of specific risk factors

- Which tree risk complexes do you see as the biggest threats to a cargo-/value accumulation and how would you prioritize them?
- How important is the vulnerability of cargo in case of an accumulation risk in your opinion?
- How important is the business-continuity relevance of cargo in case of an accumulation risk in your opinion?
- How likely do you think it is that an accumulation loss can affect the business continuity of your company?