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Supply Chain Risk Management Frameworks and Models: A Review

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Abstract— **Supply chain risk management (SCRM) is a relatively new scientific discipline aiming to support management in its everyday struggle against the inherent uncertainty of supply chain operations propagated mostly by demand and supply fluctuations, in terms of yields, capacity, costs and lead times. This paper focuses on a literature review of available SCRM frameworks and models. Using an appropriate combination of keywords, three established academic databases and a hard inclusion criterion, a final sample of 16 (starting from 922) relevant and above all, empirically validated SCRM frameworks/models papers are retrieved and studied in full. Following a systematic literature review approach and supported by a content analysis tool, the authors produce some useful results on the current research status and identify some of its shortcomings, which have to be addressed by researchers in the future, i.e. the immaturity of research in the field, the absence of a holistic approach for SCRM and finally the lack of a systematic approach to successfully identify risk propagation across contemporary and complex supply chain networks.**

Keywords— *Supply chain risk management, Frameworks, Models, Risk management, Supply chain management, Systematic Literature Review, Content Analysis*

1. Introduction

Contemporary supply chains networks are complex by nature and cannot be studied as a part of dyadic relationships among participating entities [1]. Risk is an inherent element of every supply chain network [2]. However, many firms inadvertently introduce more risks in their supply chain networks, striving for efficiency or trying to act independently [3], [4],[5]. Risk is defined as the "variation in the distribution of possible outcomes, their likelihoods and their subjective value" or in risk management terms, as "the probability of a

given event multiplied by the negative business impact it has" [6]. Still, risks should not always be considered as negative because often they reveal new opportunities and chances in a firm [7].

In the context of supply chain management, several definitions of risk exist in literature [8],[9],[10]. A common ground definition can be found in with the most prominent being the following ' In this paper we adhere with the following definition: "supply chain risk is the potential occurrence of an inbound supply incident, which leads to the inability to meet customer demand [11]. Supply chain risks are attributed to network, social and institutional processes and actions of each node in the supply chain, from the initial supplier to the end user, and may affect the company's and the supply chain's objectives regarding meeting customer demand, value, quality, time or costs [12].

Risks, in contemporary supply chain management emerge from many different sources and their appearance has increased due to some recent trends that supply chains tend to adapt [13]. The main trends that increase supply chain risks are globalization and outsourcing. Supply chains have expanded the last decades from national to international [14] benefiting from reducing costs and improved reliability and cooperation with overseas markets [15]. However, managers and practitioners tend to face many issues in the international level, as the environment is constantly changing and uncertainty is raised due to potential economic or political inconsistencies. Many risks derive also from outsourcing, among them supplier failure, disruption of production, employee alienation and loss of knowledge capital and misunderstandings due to language, cultural and geographical discrepancies [16],[17]. Those two factors are not the only ones contributing to the increase of risk in contemporary supply chains. Specialized factories, centralized distribution, reduced supplier base, increased volatility of

demand and technological innovation have also contributed to the creation of an unstable and uncertain environment [13].

The realization of risk management's importance for the operation and ultimately the viability of contemporary supply chains have led to a surge of research efforts dealing with the issue and subsequently to the practitioner's awareness on the subject [18],[19]. Terms like 'uncertainty', 'disturbance', 'disruption' and 'crisis' are very common between scholars and practitioners of the SCRM. Uncertainty is a term that creates several ambiguities since it has been observed to be used interchangeably with risk, although they have distinct technical meanings [10]. It can be described as a specific situation of a risk, lacking information and knowledge in order to identify the possible outcomes, their likelihoods and the solutions to them [20]. Usually uncertainty does not describe a situation with pre-set parameters, such as outcomes or consequences [21]. Disturbance is the perturbation of tranquillity or a set situation occurring from a risk in the supply chain. Disturbances might create fluctuations in the process of demand/ supply and can affect negatively the supply chain for a certain period. Usually disturbances are avoided by adopting certain regulations [9], [7]. The term "disruption" is also used frequently in order to describe an abrupt stoppage of supply chain operation and should be separated from that of disturbance. Disruption is defined as "an action of rending or bursting asunder; violent dissolution of continuity; forcible severance" [22]. The effects and the duration of a disruption are much more impactful than those of a disturbance. Examples of disruptions are riots, political instability, natural disasters that affect the economic performance [23]. Finally, the term "crisis" is frequently referred in supply chain risk management literature and seems to be often confused from inexperienced practitioners. Crises in supply chains are unpredictable [24] and refer to the interruption of one or more supply chain processes that affect the flow of services in a high and undesirable degree [25]. The impact that crises have on a supply chain can be more severe than a disruption and usually they are handled through specific supply chain crisis management methods.

In today's crisis prone and unstable business environment, risk management has become a central issue of concern for both researchers and supply chain practitioners. Supply chain risk management (SCRM) constitutes the field related to the identification and elimination of elements of uncertainty in the supply chain propagated by demand and/or supply related fluctuations, e.g. demand variability, unstable supply lead times etc. [26]. Generally SCRM focuses on three core areas of research: the design of the product supported by the supply chain; the supply chain itself, including location of inventories, transportation modes, and sourcing arrangements; and the operational control of the supply chain, including emergency/crisis response [27]. As in the modern era crises emerge more often and supply chains have to face them (ibid), SCRM gains increasing interest by both researchers and practitioners coping to develop SCRM strategies and introduce novel SCRM frameworks and models, consisting of formative elements or constructs to deal with supply chain risk [28]. The research presented in this paper, evaluates the current state of the art in the conceptualization and development of such frameworks and models and provides guidelines for future research.

In the next section, the methodology procedure for obtaining and processing literature review items is presented followed by a detailed description of the study's results, in Section 3. Finally, in Section 4, the results are discussed followed by the identification of research limitations and prospects for further research.

2.   Review Methodology

The first step of the methodology entails the clarification of the core study concepts and the differentiation between the terms "frameworks" and "models", which are often confused and perceived as the same notion, especially from practitioners. In essence, frameworks and models differ mostly on their objective orientation. Models are representations of "target" systems existing in the ambient world, may they be systems of words, numbers, pictures, programs, actions, and concrete images that constitute scientific communications [24] and are developed to answer "how to" questions. Frameworks can be seen as structures that provide elements, ideas and guidance in support of a topic area and are developed to answer "what is" questions [29]. Specifically, a framework represents a system with the activities carried out in it and their empirical interrelations. It provides the

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guidelines for the steps that should be followed to a certain discipline from organizations, constructing each step from the preceding. On the other hand, models represent or explain mechanisms and operations (ibid). Models may be used to idealize situations in a given framework through assumptions or simplifications [30].

In the research described in this paper, frameworks are considered as conceptual constructs of a sequence of activities, delineating their formative elements in order to serve their original purpose. Models in supply chain risk management, on the other hand, are non-prescriptive and the formative elements composing them enhance only decision making. They exist to explain a certain mechanism or an operation.

2.1 Methodology

The research presented in this paper adapts a systematic literature review (SLR) methodology with the support of NVivo content analysis. SLR has certain principles such as transparency, inclusivity, and heuristic nature and eliminates partiality phenomena leading to more objective results [31]. NVivo is a qualitative research software that enables data analysis and utilizes content analysis methods to enhance transparency and objectivity in research endeavours. Initially, texts and documents are coded and, next, the content is interpreted, discussed and revised [32]. The main goal of the content analysis is the "identification and recording of relatively objective characteristics of messages" [33]. By adapting this method, we aim to develop the literature review of SCRM frameworks and models and reinforce accuracy and candour. The methodological steps of the literature review presented in this paper are shown in Figure 1, as adapted to the current study from the works in [34].

2.1.1 Locating Studies

The research presented in this paper utilized information harnessed from three established academic databases, i.e. Emerald Online, Science Direct and Scopus. Our initial attempt for literature search combined the keywords "supply chain risk management" and "framework", "supply chain risk management" and "model", found anywhere in the article to identify research efforts relative to supply chain risk management frameworks and models.
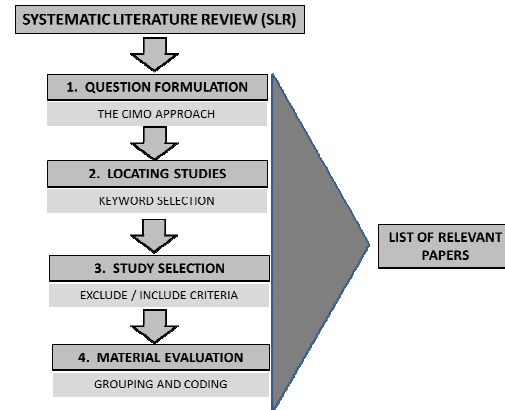

Figure 1. The Systematic Review Approach

A first abstract-based study of the produced relevant papers revealed that some well-known contributions were still missing, so the authors decided to expand the search by including the keywords "supply chain" and "risk model" and "supply chain" and "risk framework", found anywhere in the text. This expansion produced nine hundred and twenty two research papers, which constitute the sum of contributions studied within the context of this review.

2.1.2 Study Selection

Although organizations have often overlooked the critical exposures and risks along their supply chains in the last fifteen years, supply chain risk management has drawn significant research attention, acknowledging both the complexity of its structure [35] and the multitude of vulnerabilities supply chain networks present. Despite this swift of academic research towards supply chain risk management, the focus towards conceptual structures, such as models and frameworks for SCRM, is limited and thus can be considered as a new and fertile ground for exploration.

A comprehensive approach would dictate that all retrieved papers should be read in full and reviewed. Unfortunately, this was deemed inefficient. Instead, and after reading all the abstracts and assessing the content for relevance with our study, 45 papers were selected for full assessment. After reading the articles, we further filtered our sample, targeting to publications dealing with procedural frameworks and models which are further applied and validated in real life business practice. Our screening process resulted in a sample of sixteen (16) publications with a clear

proposal for a SCRM framework or model further supported with a sound and well described method of validation.

2.1.3   Material Evaluation

Next, the selected papers were categorized in three major groups further decomposed in seven dimensions related to SCRM frameworks and models dealing with methodological and practical issues, as shown in Table 1. Categorization was assigned to three independent experts in the area of SCM, with significant experience as reviewers in scientific journals and conferences. Initial categorization proposed by the experts was discussed with the authors, until a final consensus was reached [36].

Table 1. Review Dimensions

Group	Dimension
1. Descriptive Features	1.1. Year of Publication 1.2. Journal Name 1.3. Industry 1.4. Business area of application
2. Formative Features	2.1. Formative Elements
3. Research Methodological Features	3.1. Method of Framework/Model Validation

The first group provides a timeline of publications while at the same time reveals trends of industry and business areas of application. The second group identifies the formative elements of the proposed frameworks and models. Last, the research methodological group examines the research methods used for testing and supporting the framework/ model validity. The proposed grouping and dimensions come as a result of experts and authors consensus, who agreed that they provide a sound comprehensiveness of SCRM frameworks and models and their presentation in literature.

Finally, in order to eliminate human error NVivo was used for material evaluation, creating a literature archive that can be easily used for future research [37]. The results extracted from the reviewers were re-examined by coding the text using clear definition to the coding process to reassure the validity of the outcomes. Using NVivo, a database was created, which properly clarifies all review dimensions and identified any inconsistencies in the formation and synthesis of groupings.

3.   Results

SCRM frameworks and models do not have any significant presence in literature before 2003. Since then, the frequency of publication's appearance has increased; still mature publications which, apart from a conceptual construct provide some sort of validation method are scarce. In our study, we identified sixteen (16) publications fulfilling our criteria published in thirteen journals. Only three of these journals present more than one publication on the subject, these being the "International Journal of Physical Distribution & Logistics Management", "The International Journal of Logistics Management" and Emerald's "Supply Chain Management: An International Journal".

3.1   Descriptive features of SCRM frameworks and models

The classification of industries was conducted according to the Standard Industrial Classification (SIC) system that provides a four-digit for each sector. Manufacturing is the most frequent industry of application, reaching a stunning 37,5%, while our sample includes industries such as convenient stores, agriculture, construction, defense and transportation. Table 2 provides an organized overview of our findings on the descriptive features of the publications participating in our study.

As SCRM can be implemented in many different territories of activities, and can include different theories or associations, a classification of the disciplines that frameworks and models fall into, was deemed necessary. The classification is adapted from [36] and includes marketing/services, logistics, purchasing, strategy, finance, information and operations management, as shown in Table 3.

3.2   Formative features of SCRM frameworks and models

Frameworks and models are developed by certain constructs that are either sequential and represent a holistic approach of a set of processes (frameworks) or represent certain processes that explain mechanisms or frameworks in the case of models. As early as 2003, the author of [5] proposed the business-case framework [22], one of the first efforts to alter the culture of organizations

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Table 2. Descriptive features of SCRM Frameworks & Models

#	Author(s)	Article title	Year of Publication	Journal name	Industry
			FRAMEWORKS		
1	Hauser L.	Risk Adjusted Supply Chain Management	2003	Supply Chain Management Review	Miscellaneous Manufacturing Industries [3990]
2	Juttner et al.	Supply chain risk management: outlining an agenda for future research	2003	International Journal of Logistics Research and Applications:	Multiple industry sectors
3	Kleindorfer & Saad	Managing Disruption Risks in Supply Chains	2009	Production and Operation Management	Chemical industry [2800]
4	Pettit et al.	Ensuring Supply Chain Resilience: Development of a conceptual framework	2010	Journal of Business Logistics	Retail – Apparel [5600]
5	Ritchie & Brindley	Supply chain risk management and performance: A guiding framework for future development	2010	International Journal of Operations & Production Management	Agricultural Services [0700], Construction [1700]
6	Kern et al.	Supply risk management: model development and empirical analysis	2012	International Journal of Physical Distribution & Logistics Management	Miscellaneous Manufacturing Industries [3990]
7	Ghadge et al.	A systems approach for modeling supply chain risks	2013	Supply Chain Management: An International Journal	Foreign Governments [8888]
			MODELS		
8	Lee	The triple A SC	2004	Harvard Business Review	Retail – Convenience stores [5412]
9	Uta Juttner	Supply chain risk management: Understanding the business requirements from a practitioner perspective	2005	The International Journal of Logistics Management	Multiple industry sectors
10	Wu et al.	A model for inbound supply risk analysis	2006	Computers in Industry	Miscellaneous Manufacturing Industries [3990]
11	Craighead et al.	The Severity of Supply Chain Disruptions: Design Characteristics and Mitigation	2007	Decision Sciences	Miscellaneous Manufacturing Industries [3990]
12	Manuj & Mentzer	Global supply chain risk management strategies	2008	International Journal of Physical Distribution & Logistics Management	Miscellaneous Manufacturing Industries [3990]
13	Trkman & McCormack	Supply chain risk in turbulent environments—A conceptual model for managing supply chain network risk	2009	International Journal of Production Economics	Miscellaneous Manufacturing Industries [3990]
14	Foerstl et al.	Managing supplier sustainability risks in a dynamically changing environment—Sustainable supplier management in the chemical industry	2010	Journal of Purchasing & Supply Chain Management	Chemical industry [2800]
15	Ghadge et al.	Supply chain risk management: present and future scope	2012	The International Journal of Logistics Management	Multiple industry sectors
16	Johnson et al.	Exploring the role of social capital in facilitating supply chain resilience	2013	Supply Chain Management: An International Journal	Transportation services [4700]

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Table 3. Areas of Application

Business Area of application	Papers
Marketing/services	3, 5, 7, 9, 11, 12, 15
Logistics	3, 5, 6, 7, 9, 11, 12, 13, 14, 15
Purchasing	3, 5, 6, 9, 11, 12, 13, 14, 15
Strategy	2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 15, 16
Finance	1, 5, 8, 10, 11, 12, 15, 16
Information	2, 5, 6, 7, 11, 12, 15
Operations management	1, 2, 4, 5, 6, 7, 11, 12, 15

from managing risks by instinct towards a disciplined procedure supported by information deriving from risk assessment and identification. In [9] the authors develop a framework which consists of four critical aspects: assessing the risks sources for the supply chain; defining the supply chain risk concept and adverse consequences; identifying the risk drivers in the supply chain strategy; and mitigating risks for the supply chain. The framework was developed when SCRM was still at its infancy, introducing the need for incorporating more decision making relevant elements to the SCRM agenda. The authors of [10] develop a conceptual framework, based on a pathway of risk and performance drivers, consequences and responses. Distinctively, the framework introduces the term "performance" and demonstrates the inherent linkage among risks and performance. In [27] the authors propose a disruption management framework named SAM (Source-Assess-Monitor) based on four major premises that derived from empirical results of industrial risk management: specification of the nature of the underlying hazard that gave rise to the risk; risk quantification through a disciplined risk assessment process; approach solution according to the given supply chain environment; and integration of policies and actions with on-going risk assessment and coordination among supply chain partners. The authors in [13] evaluate and adapt a framework from [38], consisting of 6 actionable elements: identify hazards, assess risks, analyze controls, determine controls, implement controls, supervise and review. The authors identified that the major weakness of the framework is the inability to define

the severity of risk consequences and their probability of occurrence. By defining these factors, unforeseen disruption can be handled and supply chain will gain a competitive advantage. In [39] a framework with five constructs and six relationships is developed. The framework has four main processes; risk identification, risk assessment, risk mitigation and risk performance. The authors in [16] develop a SCRM framework adopting a systematic approach. Their framework proposes five major activities: risk taxonomy, risk trending, risk modeling, strategy planning, and risk mitigation.

The review proves that common views on risks and joint responsibility are deemed crucial, by both scholars and practitioners. Principles are more specific and concern operational and strategic decision. The processes are the lowest conceptual level and refer to explicit activities and tasks on SCRM. In [40], the authors propose a model for risk management of supply chain disruptions. They identify that supply chain density, complexity and node criticality are important and directly related to the severity of SC disruptions, whereas recovery and warning are important for risk mitigation. Furthermore, the interactions and coordination of resources can proactively manage a disruption. The authors in [41] develop a model in a global manufacturing company context. According to their model, the team composition and supply chain risk management strategies have to be identified according to the antecedents, which are temporal focus, SC flexibility and SC environment. The strategies presented in the model are postponement, speculation, hedging, control /share/ transfer, security, and avoidance. Also the model suggests that inter-organizational learning is important to handle SCs' complexity. The authors in [42] introduce the elements of assessing and classifying suppliers to mitigate the risks arising from their actions or possible non-performance. In [43] the authors are also studying supplier management capabilities regarding SCRM. Their research indicated that supplier sustainability risk needs identification, assessment, quantification of the possible consequences, decision of management responses and performance measurement. In [44] the authors identify seven crucial elements for SCRM: behavioral perceptions in risk management, sustainability factors, risk mitigation through collaboration contracts, visibility and traceability, risk propagation and recovery planning, industry

impact and a holistic approach to SCRM. In [45] the role of social capital in the resilience of a supply chain network through a case study is explored. The authors argue that social capital can increase flexibility and resilience to recover from the consequences of extreme events. Through the analysis of the case study, flexibility, velocity, visibility and collaboration were deemed as significant for the recovery of a supply chain.

In total, fifteen formative elements were identified for frameworks and twenty six for models, with nine of them identified as framework elements too, e.g. "risk identification" and "performance measurement". When different terms are used for the same element, e.g. "specification of the nature of the underlying hazard" vs. "risk sources identification" or "supervise" vs. "monitor", they are integrated in the term used more frequently, as a result produced by NVivo. Fourteen of the elements that were exclusively identified in models concern conceptual notions of SCRM such as "visibility", "collaboration" and "adaptability". Their incorporation to the strategic constructs of frameworks leads to more effective processes for risk mitigation in supply chains. The rest of the elements are more specific and refer to strategic processes, e.g. "suppliers' assessment". The conceptual elements refer to softer human-oriented constructs that are interlinked with social relationships whereas the strategic constructs concern well-defined processes about technological issues [17].

The results of the review are summarized in Table 4. With the help of our coding tool we show the frequency of appearance and volume of referencing of formative elements in the reviewed papers. The definition of each element is presented as found in the papers. One can safely argue that some constructs have been extensively discussed and incorporated in frameworks and models. The ones that are included in all papers are strategic elements; risk mitigation, risk classification and risk identification, which constitute the basic SCRM processes [46]. Despite that, all constructs are significant in SCRM. The organization's profile is crucial in deciding what strategy will be followed [41]. Key performance metrics and initiatives provide an operational control in the procedure and assist the implementation of the decided solution and the monitoring and measure of the organization's performance [5]. Last, integration is

a key part of SCRM, as policies and actions should be integrated in the procedure to avoid and handle more effectively future risks and disruptions [5], [44].

3.3   Research Methodological Features

Theories are tested with many different methods and examining how the frameworks and models are validated can provide more insights on the direction of research in the respective field. In this study, we identified several methods of supporting research validity including interviews, focus groups, qualitative and quantitative analyses to empirical data collected from industrial organizations. The most frequent method used is the case study, followed by the application of a combination of more than one method (see Table 5). In the same table, the number of applications of the research validation method is noted, as a measure of the method's impact, usability and effectiveness.

Table 4. Formative Elements (Frequency of appearance, # of references)

#	Name	Sources	References	Definition
1	Risk classification	16	290	Assortment and categorization of risks through specific criteria
2	Risk mitigation	16	332	Application of certain strategies for mitigation and moderation of risks
3	Risk identification	16	318	Discovery of the occurrence of a risk
4	Risk sources identification	15	302	Ability to map the multiple sources and drivers of risks
5	Collaboration	13	102	Cooperation with the SC nodes effectively
6	Solutions determination	12	37	Decision of the method that will be followed to mitigate risks
7	Agility	9	53	Ability to be ready and respond immediately
8	Interaction	9	29	Ability to act reciprocally
9	Performance measurement	9	49	Calculation of the SC performance
10	Sustainability	9	270	Maintenance performance at a stable level
11	Adaptability	8	91	Alteration of operations in order to respond to possible challenges
12	Performance monitoring	8	34	Supervision of the SC performance
13	Policies integration	8	27	Capability to add together or combine rules to the existing ones
14	Flexibility	7	34	Ability to rapid alteration of the existing modes
15	Sources coordination	7	101	Ability to place different nodes and make them synchronize and work effectively together
16	Risk quantification	5	12	Capability to calculate and measure risks according to specific criteria
17	Inter-organizational learning	4	21	Development of awareness and knowledge transmission to the internal stakeholders of the SC
18	Possible solutions identification	4	12	Discovery of the solutions that could be implemented
19	Alignment	3	19	Ability to bring SC nodes in a correct relative

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20	KPI identification	3	6	Indication of the metrics that define if the SC performance
21	Transparency	3	8	Ability to have visibility throughout the SC
22	Density identification	2	6	Definition of the degree of enough consistence and needs in the SC
23	Organization's profile definition	2	5	Identification of the schematics and the strategies the SC uses
24	SC complexity definition	2	5	Comprehension of how complicated the processes of the SC are
25	Supplier assessment	2	11	Evaluation of the suppliers
26	Velocity	2	23	Ability to rapidly execute and manage processes
27	Critical nodes identification	1	10	Recognition of the nodes that may be more affected than others
28	Improvement	1	17	Ability constantly progress and increase performance
29	Initiatives development	1	3	Implementation of the metrics indicated
30	Joint responsibility	1	2	Ability to have common accountability on actions from all stakeholders
31	Supplier classification	1	6	Categorization of suppliers according to specific criteria
32	Temporal focus	1	5	Adaptation of short-term but effective SC strategies

Table 5. Methods Supporting Framework/Models Viability

#	Verification mode	Frequency
1	Case study	Single
2	Exploratory interviews	Single
3	Qualitative analysis of empirical data	Range 1995-2000
4	Focus groups	8 focus groups
5	Case studies	Two
6	Literature review, qualitative analysis of surveys	Single
7	Quantitative analysis, case study	Single
8	Case study	Single
9	Focus group	6 focus groups
10	Case study, in-depth interviews	Single
11	Case study, interviews, focus group	Three times
12	Focus group, in- depth interviews	Single
13	Case study	Single
14	Case study	Single
15	Cross-validation with text mining	Range 2000-2010
16	Qualitative analysis of empirical data	Three

4. Discussion and Further Research

SCRM is a scientific field under development, since its first well established instance in literature dates back in 2003. Although it has attracted a lot

of attention in the last decade, the specific area of SCRM framework/model development seems overlooked. This becomes evident in our study, which originating from an initial sample of 922 papers, we only managed to identify 16 research papers satisfying the study's criteria. It has to be noted, that even if one alleviates the hardest criterion of our approach, which is the existence of some form of framework's/model's validation, even then, only 45 papers would have managed to reach the last stage of our paper selection process. As for the sources attracting SCRM researchers, in their majority come from the Supply Chain Management, Logistics and Production and Operations Management field. Finally, manufacturing is the dominant test-bed industry for almost half of the reviewed papers, revealing the necessity for a broader perspective reaching more industries, thus enhancing the validity of the proposed frameworks/models.

This research identified 32 discrete and not overlapping formative elements of SCRM frameworks/models studied. It is true that some of the elements are referenced more than others, forming a weak, but not to unnoticed, indication of their significance and importance. However, we argue that one should take into account the sum of the identified elements as they all have a justified significance towards the common objective of a holistic approach of supply chain risk management. Furthermore, the difference of the strategic or conceptual nature of the constructs indicates that there are some difficulties in approaching SCRM in a holistic fashion. Finally, case study seems to be the 'weapon of choice' when it comes to validating research results, followed by focus groups and the combination of more than one methods. Unfortunately, the multi-disciplinary nature and the plethora of formative elements of SCRM theoretical constructs make the adoption of more analytical and 'hard' methods very difficult. Our research reveals the need for broader and more solidly validated studies in the field, which will alleviate current reservations about critical factors of a model/framework's success, such as reusability, generality, applicability and adaptability.

Apart from the aforementioned limitations of current research in the area of SCRM, one major shortcoming has to be further discussed. There is a lack of breadth in the research approaches when it

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comes to model/framework building and thus a holistic and continuous approach is lacking. The most striking element of this shortcoming is the absence of specific elements or even processes that capture and deal with behavioral and social aspects of SCRM. Behavioral aspects such as managers' decision making, team composition, the decision of the right strategy are often omitted because of their difficulty to be captured and modeled. Nevertheless, behavioral aspects directly impact risk mitigation and should constitute a core element of SCRM frameworks and models [44], [28], [41].

Early research efforts approached SCRM through qualitative research and empirical studies. Later on, algorithm based quantitative techniques [47], evolutionary algorithms, game theory [48] and simulation [45] have been used for studying SCRM problems and provide plausible solutions. All of these studies do not follow a holistic approach on risks management. In addition, some frameworks and models were validated on a specific industry context [27], [40], [10], [41].

More dynamic and cross-disciplinary approaches have to be implemented to incorporate behavioral aspects and approach SCRM holistically [34], [49]. The systemic framework, proposed in [16] captures the complexity of the interconnected nodes of a supply chain, as it studies the influence of multiple risks on a supply system network and proposes a methodology to depict risk propagation. The proposed model bridges risk modeling theory and practice, providing a holistic, systematic and quantitative risk modeling approach to SCRM. However, it fails to adopt the dynamic nature of decision making and behavioral attributes in the framework. On the other hand, frameworks and models that adopt behavioral aspects [2], [41], [42] are lacking the strength of quantitative risk assessment that one can find in the works of [16]. The absence of a hybrid approach, with strong foundations and tools for both hard and soft SCRM parameters is evident in contemporary literature.

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