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Do risk events increase supply chain uncertainty? A case study

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ABSTRACT

Supply chain uncertainty has become an important area of research, and it is crucial for many firms, and especially so for global firms. Decision makers find it difficult to make decisions due to lack of transparency in the supply chain and the impact of possible risk events. This paper aims to approach this topic by developing a conceptual model to assist logistics and supply chain managers to improve supply chain effectiveness by analysing risk events. To this end we use a case study based on a set of interviews with agents of a German firm and some of its suppliers from India, China and Europe, which generates insights uncaptured in previous research in the area. The main findings answer questions such as: 1. How to build an agile supply chain strategy with rapid planning and integrated execution in different stages?; 2. How to identify and avoid risk events as they increase the supply chain uncertainty and are multiplied when interrelated risk events occur simultaneously; 3. Can supply chain uncertainty be reduced by determining the degree of flexibility required to mitigate risk effects, reducing supply chain uncertainty and increasing the firm's dynamic capabilities?.

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1. Introduction

Logistics plays a crucial role, not only as a cost factor, but also as a major success factor for firms. Even though the dilemma faced by decision makers when it comes to choosing the most appropriate supply chain strategy has been studied by many researchers in the past, such as Beck and Hofmann (2012), firms are more and more pushed into specialising in a certain business and are strongly influenced by political policies, custom regulations and reliability of logistics providers. The ability of firms to build and manage an appropriate network is key to their business success. Supply chain managers are focused on designing an action plan to avoid, prevent or mitigate supply chain disruptions, reduce supply chain costs, and increase supply chain transparency and bidirectional and transparent communication with their partners. This

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study aims to provide further insights into logistics by performing a case study focused on a firm located in Germany and some of its suppliers from India, China and Europe. This research focuses on the firm-supplier-subcontractor relationship as a network, paying special attention to the customer's viewpoint. When a firm faces changes to demand and/or supply it requires scenario planning to rapidly match supply and demand to operational changes.

In an increasingly competitive, dynamic, instable and globalised environment, yesterday's processes and statements are not valid today, and what is valid today will not be valid tomorrow. External threats are continuously spoken about in the newspapers, TV, etc. A possible financial crisis for the year 2020 was even announced many years ago. Natural catastrophic disasters such as tsunamis or pandemics like COVID-19 can lead to disruption and shortages in the supply chain (Mckinsey, 2020) and have a global macroeconomic impact (McKibbin & Fernando, 2021). In fact, multitudinous events have been postponed or cancelled in light of the risks posed by the Coronavirus pandemic.

Another threat for supply chains is climate change. What is climate change and how does it affect firms? It is more than a political movement established in rich countries to make cosmetic changes like the 'Fridays for future' initiative. Lately, researchers like Heinold and Meisel (2019) tackle this topic with their study 'Emission oriented versus time oriented routing in the European intermodal rail/road freight transportation network', a paper that was awarded the DHL prize at the logistics conference in Halle (Germany) on September 2019 (Bierwirth et al., 2019). However, due to scale economies, most electronic components are supplied from Asia. How are sustainability standards weighted in Asia? How is infrastructure designed in Asia? What risks arise from the current protectionist economic policy? In particular, import restrictions through methods such as tariffs on imported goods, import quotas, and a variety of other government regulations can even lead to making firms bankrupt and require changes in the supply chain strategy and in overall firm strategy.

This is not the time to ignore these isssues, but may be the time for firms to make changes in the way decisions are taken, which will lead to future consequences for our descendants. Governments, and especially firms, should be aware of their corporate social responsibility and evaluate what this represents for the community. Globalisation brings international and local consequences. Specifically, political decisions taken in the USA can directly affect firms located in Germany or China. In addition to this, the dependency of firms increases exponentially for global players and firms who design an offshore supply chain strategy. Effectively managing the supply chain should involve external providers, subcontractors, logistics service providers and their coordinated integration from tier-n to final delivery (World Wide Shipping, 2019). The problem addressed in this study includes analysing the influence of risk events in logistics. In the Introduction, the goals of our research questions could be better substantiated with previous research. In addition, the inclusion of empirical data collection can support the explanation of the findings, not being a research question itself. For this purpose, this research examines different types of risk mitigation strategies that call for different types of flexibility and it has three primary goals: (1) review and update the literature on Sustainable Supply Chain Uncertainty (SSCU); (2) determine possible supply chain risks; and (3) collect

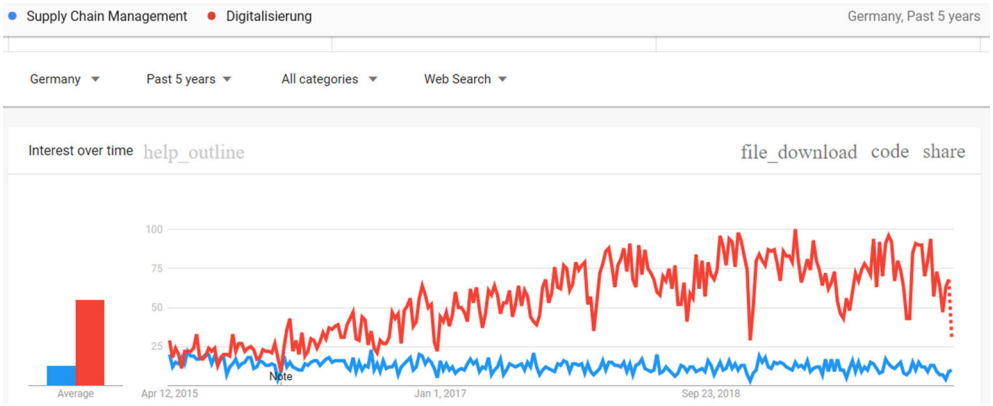
evidence from a set of interviews with practitioners from a case study. This evidence can be used to make recommendations to improve SSCU. The rest of the paper is organised as follows: Section 2 analyses and reviews the literature on supply chain uncertainty and risk management. Section 3 proposes, presents and describes a model to evaluate SSCU based on risk events analysis. In Section 4 the data for the research is collected, based on a set of interviews from a case study. In Section 5, the proposed model is validated through a case study based on a firm located in Germany and its suppliers in India, China and Europe, and findings from experimental evaluations and analyses are presented to assess the effectiveness and efficiency of the proposed model. Finally, the main conclusions and related topics for future research, as well as the limitations, are discussed and presented in Section 6.

2. Sustainable supply chain uncertainty: concepts

This section analyses and reviews the literature on supply chain uncertainty and risk management, mainly focusing on relevant literature such as the research of Medina Serrano, González-Ramírez, and Gascó-Gascó and Llopis-Taverner (2021). There are different management concepts associated with supply chain management in general and logistics in particular. The ripple effect describes the impact of disruption propagation on supply chain performance, structural designs and operational parameters. Whereas the ripple effect appears when the impact of a disruption cannot be localised and it spreads along the supply chain (Dolgui et al., 2018; Ivanov, 2017) affecting its performance, the domino effect refers to how one risk event can spread like a contagion to related risk events. The push effect occurs when risks are linked, increasing the severity of each and every risk effect on outputs. Quang and Hara (2018) developed a hypothesised model describing the push effects among supply chain risks. According to Dolgui et al. (2018), material flow disruptions pose a serious threat to today's supply chains as risk exposure and associated risk consequences increase, particularly as a result of stronger global and international dependency. Struve et al. (2019) develop a Data Envelopment Analysis of sustainability performance in a triple bottom line approach for the automotive industry and test this approach with real life business data from firm reports. A review of the papers presented at the German logistics congress celebrated in September of 2019 (Bierwirth et al., 2019) is performed.

Digitalisation in supply chain management is relevant to this study. In fact, the popularity of digitalisation is continuously increasing, especially in supply chain management. This can be seen through the Google Trend application, which provides an overview of this trend over the years and different countries (Google Trend, 2020). Figure 1 illustrates the importance of digitalisation over the last 5 years in Germany. It shows increased concern with integrating physical processes with digital data to create a fully optimised supply chain.

According to Mckinsey (2019), the supply chain management of industry 4.0 entails the automation of anything, analysing everything, and creating networks everywhere to significantly improve supply chain performance and customer satisfaction. Whereas Klumpp and Ruiner (2019) suggested that individuals with high self-efficacy are more proactive and show greater intuition in digital logistics, Flechsig



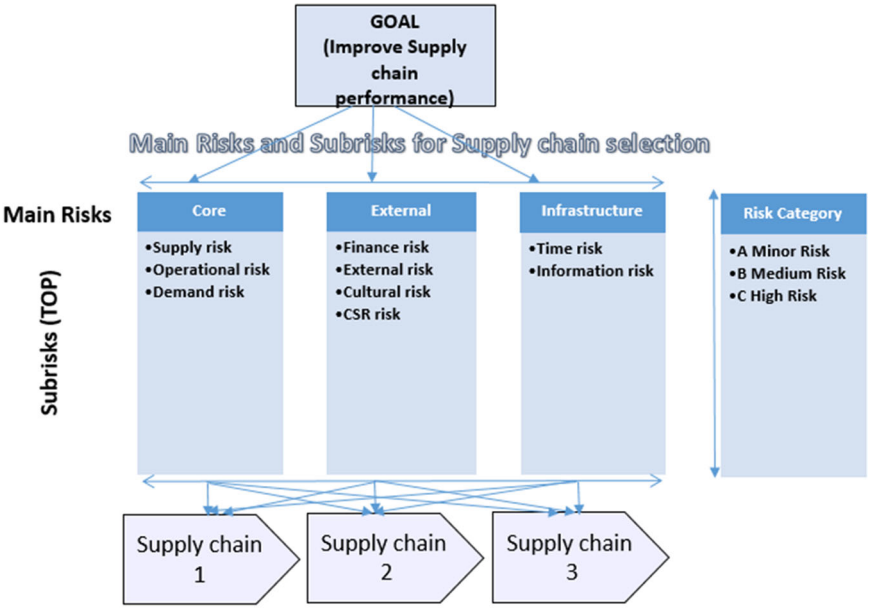
Source: Google trend (2020)

Figure 1. Supply chain digitalisation.

et al. (2019) argued that digitalisation and process automation activities have increased in recent years. Optimisation through the combination of Robotic Process Automation Business Process Management, and digitalisation has enabled firms to efficiently manufacture products, reducing supply chain uncertainty. Both, Straubert et al. (2019) in their content analysis and Bask et al. (2012), in their literature review, identified the significance of the trend towards faster deliveries in logistics. Also, Fawcett (1992) suggested that lead times are important for the success of a supply network. Siller (2019) stated that besides lead times, carbon emissions play an important role in the configuration of a supply chain, especially due to governmental regulations. According to him, 'Delivery lead time is the time needed to fulfil a customer's order of a product in a period and consists of transportation lead time, procurement lead time, manufacturing lead time, and handling lead time in the warehouses'. Whereas Heinold and Meisel (2019) suggested that emission reductions in the freight transport sector can be achieved by a corresponding re-routing of shipments, De Miranda Pinto et al. (2018) stated that intermodal road/rail freight transportation is more environmentally friendly than unimodal road-only transportation. A different routing of shipments will influence transportation costs and transportation delays. Heinold and Meisel (2019) used the terminal-and-service selection problem to find optimal routings, comparing Emission Oriented versus Time Oriented Routing in the European Intermodal Rail/Road Freight Transportation Network. Struve et al. (2019) found, in their research on Sustainability Evaluation in Automotive Supply Chains with a DEA, that different Original Equipment Manufacturers have very distinctive sustainability settings and results. Thus, different firms with the same figures will have different outcomes, which leads to a need for standardisation.

3. Sustainable supply chain uncertainty-risk analysis model

To deal with uncertainty in a sustainable supply chain a model is proposed. The model, illustrated in Figure 2, is based on the guidelines proposed by Miles and



Source: Case study

Figure 2. Proposed model.

Huberman (1984) and the posterior implementation of Cánez et al. (2000), explaining graphically the main dimensions to be studied. The model adapts and extends the original risks defined by Quang and Hara (2018) with CSR and cultural risks; these risks being the effect of uncertainty on expected results. The proposed model is also based on the analytic network process (ANP) methodology, which was developed by Saaty (1996), and the subsequent implementations by Gencer and Gürpinar (2007). Main risks (external, infrastructure and core risks), defined according to Quang and Hara (2018), are split into sub-risks and analysed to find the best supply chain option (Supply chain 1, 2, 3, etc.). In this sense, the conceptual model is split into five stages: (1) overview; (2) analysis of risks (Figure 2); (3) classify and evaluate the cumulative risks (Medina Serrano, 2019); (4) assess supply chain performance and create an action plan (Medina-Serrano et al., 2019a); (5) re-evaluate supply chain performance taking into account the defined main risks and a checklist split into core, external, supply chain performance and infrastructure fields. The conceptual model is outlined in Figures 4-1 and 4-2 of the annex, which is also applied in this paper. This collects insights into the supply chain risk management from the buyer's perspective, as was previously performed by Medina Serrano et al. (2021). Step 1 outlines the supply chain risk analysis, supply chain risk category and supply chain performance assessment blocks. Step 2, based on the ANP, structures a decision problem into a network using a multi-criteria decision analysis (Saaty, 1996). This proposed model for supply chain risk analysis is linked and integrated with the results of Medina-Serrano et al. (2019a) and Medina Serrano (2019) dissertation. Logistics and reverse logistics risk events can be analysed through this model (Figure 2). The phases of firms' internal processes, distribution and customer delivery as part of the logistics strategy are not

included in this study, as they are addressed in another paper. In Step 3 risks are measured on two dimensions – the likelihood of occurrence and the impact if the event occurs (see Figure 4-1 of the annex). In this paper, different types of risk mitigation strategies are examined that call for different types of required flexibility. Step 4 defines three main clusters for the evaluation of sustainable supplier performance in terms of economics, environmental and social. Step 5 collects a number of questions, which can be used as a checklist split into core, external, supply chain performance and infrastructure fields (Figure 4-2). For example, whereas a multiple source strategy is recommended for major risks, a master supply agreement with specified flexible manufacturing activities or with the possibility to agree a quantity of semi-finished goods is recommended for medium risks so that the firm has the possibility to quickly react to demand changes. No actions, or minimal actions are required for minor risks.

4. Data collection methods

In order to carry out the empirical study, main data is collected from a set of interviews with agents from India, China and Europe. The case study focused on a leading manufacturer of electronic products based in Germany with 1669 employees and a €275 m turnover (key figures from the end of 2019). The main criteria for the selection of this firm were that the firm (1) identified a need to improve its SSCU, (2) had recently performed supply chain risk and logistic evaluations; (3) German global players represent a model for other European firms; and (4) this is a convenient case study, as one of the authors has a relationship with the firm . The interviewees from the studied firms, listed in Table 1, are involved in purchasing and logistics planning.

Additionally, a systematic literature review was carried out in a previous paper (Medina-Serrano et al., 2019b) to collect data as a basis for the model, structuring digitalisation relationships (Fisher & Aguinis, 2017) and ensuring completeness and reproducibility of the results (Elsäßer et al., 2019). In this previous paper, multiple strategies around the simultaneous use of supply chain management designs were outlined and are taken into account for the case study's interviews. Besides this literature review, an empirical qualitative evaluation was required, which will lead to more cross-industrial supply relationships. Thus, the review contains material that goes beyond the scope of purchasing, logistics and supply management. The paper focuses on the procurement phase between firms, their suppliers and their subcontractors, evaluating supply chain and logistics risks in order to meet the respective customer and product needs. The question of evaluating logistics risks in global supply chains is often answered quantitatively. However, dedicated management also requires qualitative approaches to evaluate the existing situation adequately. By applying a qualitative approach, this research considers supply chain risks with a sustainability evaluation, matching key performance indicators.

To undertake the case study, information was collected on how previous SSCU evaluation decisions had been approached. The case study will be useful to understand whether risk events in logistics increase supply chain uncertainty in practice. Lessons learned from interviews with decision makers (purchasers, logistics and

Table 1. Overview of the firms investigated.

Evaluation's criteria	Firm A	Firm B	Firm C	Firm D	Firm E	Firm F	Firm G
Main business	Manufacturer of inductive components	Manufacturer of printed circuit boards	Manufacturer of precision-engineered products	Manufacturer of printed circuit boards	Electronic Manufacturing Services (EMS) provider	Manufacturer of injection molding parts	Impregnation services
Country	India, Gurgaon	India, Mumbai	India, Bangalore	China	Slovakia	Germany	Germany
Firm's size	Small-SME	Small-SME	Upper-SME	Large corporation	Small-SME	Small-SME	Small-SME
Number of employees	82	161	3000	2100	200	19	19
Turnover	€ 1	$4.63 m	$200 m	$198 m	€ 12	< €1	< €1
Firm with customer' country support	No	No	Yes	Yes	Yes	Yes	Yes
Kind of transportation	by plane	by plane, shipment	by plane	by plane, shipment possible	Weekly Trucks	Truck	Truck
Main logistic providers	DHL, FEDEX	DHL, FEDEX	DHL, FEDEX	DHL	Arrange with expedition partner	DHL	DHL, or pick up from the customer
Main criteria	Factory close to the airport	Factory close to the airport	Factory close to the airport	Factory close to the airport	No borders charges	Factory close to the customer	Factory close to the customer
Delivery time	Make to order / forecast agreement with the customer	Make to order / forecast agreement with the customer	• 6 to 10 weeks from PO to release (serial production) • 8 to 10 weeks for initial samples	A fast prototyping line is available in Germany • 6 to 10 weeks from China	Make to stock / Raw material purchased previous forecast and frame contract agreement with customer	Forecast agreement with customer	Single orders, fast delivery
Frame contract	No	No	No	Not in place, but forecasts	Yes	No	No
Certification	ISO 9001 (Manufacturing), ISO 18001 (Occupational Health), ISO 14001 (Environment)	ISO 9001 (Manufacturing) ISO 13485 (Medical)	ISO 9001 (Manufacturing), IATF 16949 (Automotive), ISO 14001 (Environmental) ISO 45001 (Occupational health and safety)	ISO 9001 (Manufacturing), ISO/TS 16949 (Automotive), ISO 13485 (Medical), ISO 14001 (Environment) complies with the U.S. Dodd-Frank Act for conflict minerals	ISO 9001 (Manufacturing), IATF 16949 (Automotive), ISO 45001 (Occupational Healthy), ISO 14001 (Environment)	ISO 9001 (Manufacturing),	ISO 9001 (Manufacturing), ISO 14001 (Environment)
Custom issues	India custom restrictions	India custom restrictions	India custom restrictions	China custom restrictions	No, EU country	No, same country	No, same country
ERP system	No	Yes	Yes	Yes	Yes	Yes	Yes

Source: Case studies.

supply chain managers) are collected in order to understand the interrelation between the firm, third parties and the factors and possible outcomes of supply chain risk events. In order to do this, a number of interviews were undertaken with decision makers from India, China and Europe. The interviews, their design, the analysis of the transcripts and how the findings were incorporated into the framework are described here.

Semi-structured interviews with decision makers were carried out. An interview questionnaire with a preliminary model was designed and served as an interview guide. Interview sessions took over one hour and mainly covered the following topics:

- details of the interviewee
- areas related to supply chain risks
- possible SSCUs
- potential logistic advantages (like tax free zones)
- criteria to be considered during the SSCU evaluation
- functions involved in the SSCU evaluation process
- criteria for the SSCU evaluation decision taken in the organisation
- strengths and weaknesses of ongoing and past supply chain decisions with focus on logistics
- lessons learned and suggestions from ongoing and past decisions
- stages taken into account during the SSCU evaluation process

The results of the interviews are linked to the findings in Section 5. The case study was carried out using evidence from multiple sources, such as consignment stock agreements, non-disclosure agreements, confidential disclosure agreements, supplier self-disclosure forms, supplier selection assessments, quality assurance agreements, supplier audit reports, delivery contracts, purchase orders, purchase order confirmations, supplier delivery performance reports, correspondence concerning import and export goods between custom authorities and external logistics providers, regular communication transcripts, final reports, demand planning and forecasting configuration at SAP and project plans, with a view to gaining validity and reliability (Yin, 2018). The case study will also be useful to refine the model and illustrate how to use it. In order to re-evaluate supplier performance, the authors propose implementing the framework developed by Medina-Serrano et al. (2019a) based on the triple bottom line methodology. Applying this framework, supply chain evaluation of the procurement process for a product or service can be addressed. Thus, the effectiveness of the measures defined in the risk action plan and their posterior implementation can be systematically evaluated. There is a worldwide trend to implement and monitor key performance indicators (KPIs), which leads to a massive amount of data to process. Contradictions about supplier evaluation criteria and their subsequent supply chain performance leads to different outcomes being interpreted. Research results propose the use of the same framework and criteria (social, environmental and economic) for the first supply chain evaluation and a re-evaluation after implementing the corresponding actions to mitigate or prevent risk.

5. Findings from the case study

The external providers involved in this case study are based in India (Firms A, B, C), in China (Firm D), in Slovakia (Firm E) and in Germany (F, G). Firm A is a manufacturer of precision-engineered products using Metal Injection Moulding as the core manufacturing technology and is a global player based in Bangalore, India, with manufacturing facilities in the USA and Bangalore. It has approximately 3,000 employees and a $200 million revenue (Key-Figures from 2018). The firm is ISO 9001 (Manufacturing), ISO 16949 (Automotive), ISO 14001 (Environmental) and ISO 45001 (Occupational health and safety) certified. Firm B is a manufacturer of inductive components and is located close to New Delhi, India. It has approximately 82 employees and a €1 million revenue (Key-Figures from 2018). The Firm is ISO 9001 (Manufacturing), ISO 18001 (Occupational Health), and ISO 14001 (Environment) certified. Additionally, the firm adopted the Customer's external provider code of conduct, which contains the main social criteria defined in ISO 26000 and it also complies with RoHS, REACH and conflict minerals directives. Additionally, the firm has an internal code of conduct which contains the main social criteria defined in ISO 26000. Firm C is a manufacturer of printed circuit boards and is a global player based in Mumbai, India. The firm has approximately 161 employees, including 125 production employees, and $4.63 m revenue (Key-Figures from 2018). The firm is ISO 9001 (Manufacturing) and ISO 13485 (Medical) certified and also complies with the Indian Space Research (AS9100). Additionally, the firm agreed the Customer's external provider code of conduct, which contains the main social criteria defined in ISO 26000. The firm has manufacturing facilities in Santacruz Electronics Export Processing Zone (SEEPZ) in Mumbai. The firm's size is categorised according to Venohr et al. (2015) definition where classic SME-type firms revenue below 50 million EUR, Upper-sized firms revenue between 50 million EUR and 1 billion EUR and Large corporations revenue over 1 billion EUR, which varies depending on the country and the business. An overview of the firms investigated is illustrated in Table 1. Firm C is located in the SEEPZ zone, a Free Trade Zone, which brings an economic advantage for logistics firms. Firms that mainly sell their products and services overseas do not incur customs duty on imported goods like raw materials. This advantage does not apply for firms that mainly focus on selling to the internal market. DHL, Fedex and UPS were named as the most used logistics providers. The common delivery time, including manufacturing time, is of 4 weeks by plane to Leipzig/Germany and 2-3 working days more to Slovakia. Also, Firm B gets tax benefits from the import taxes of purchased machinery. This firm exports approximately 95% of its turnover. Firm C invests 2% of its turnover in the community, supporting hospitals and kids projects in the city, providing drinking water facilities, cleaning local lakes, saving energy costs by switching off lights and 85% of used energy is from renewal energy (solar, wind), sensors and planting over 1000 trees. Besides complying with the RoHS2, REACH, PFOS directives, Firm D is ISO/TS 14067 (Product Carbon Footprint) certified. The characteristics of the other firms (Firms D, E, F and G) under study are illustrated in Table 1. The results are linked to the methods applied during the interviews and the main questions outlined in Section 4.

The firms investigated in this case study have multiple interrelationships. For instance, Firms D and B deliver PCBs to Firm E. Firm F delivers moulding parts to Firm A, and Firm A delivers the semi-finished parts to Firm E. After assembly and testing, Firm E delivers the product to the customer. Firm G provides impregnation services to the end customer and Firm A. Firm C is specialised in the manufacturing of certain parts. A risk event increases the supply chain costs and these costs increase strongly when interrelated risks occur simultaneously. In order to prevent or rapidly mitigate risk events, second source strategies should be implemented and activities should be regularly monitored. The risk category is calculated according to Medina Serrano (2019) dissertation risk definition, which is based on the multiplication of risk event occurrence and its degree of impact, and the research of Quang and Hara (2018). Table 2 illustrates the implementation of the proposed risk categorisation into the case study.

Due to the own paper extension limitation, only Firms A, B and C are described in detail. As part of the design of supply chain management and logistics in particular, international custom restrictions should be taken into account. Equally, required import and export customs paperwork leads to extra administrative costs. Small firms do not have an import-export department so they need customs support to understand the world of customs and its complex terminology. This could be identified in the case study, where a claim from the German custom authorities was made against the German logistics provider and the final customer concerning a delivery from Firm A to the end customer in Germany (Table 3).

One of the main benefits for the firm of applying the proposed model is the rapid identification and classification of possible risk events and the evaluation of their importance, so that risks can turn into opportunities to reduce supply chain costs. A new KPI for supplier delivery date evaluation is redefined at the firm and is illustrated in Figure 3. To illustrate, if the goods delivered by the external provider arrive on time (0 working days and 100 points); two days later than agreed (+2 and 40 points), the evaluation of the external provider for that delivery is 40%, which directly influences the external provider evaluation defined at the firm. External providers are classified as A (100–85), B (84–75) and C (74–1). Whereas A-Suppliers are preferred, suppliers classified as B have a potential for improvement and C-Suppliers have to improve or they will be blocked. Interestingly, this research identified the need to update the definition of KPIs, highlighting missing parts and the monetary impact of complaints and poor delivery, taking action plans against poor suppliers to improve their performance or replace them by others that deliver better performance. In order to react legally to supplier information about delivery delays and difficulties with regard to sourcing materials, a master letter for suppliers was employed, which contains four options to reject the reason for a delay in delivery times. These four options are (1) market situation; (2) price increases; (3) delay in lead times; and (4) allocation of products. With Option 1, the firm poses that it is every supplier's duty and responsibility to fulfil its delivery obligations towards customers, taking appropriate precautionary measures against possible delivery delays and problems and stocking products correctly to be able to deliver on time. With Option 2, the firm rejects any price increases for orders already agreed upon. In Option 3, the firm points out

Table 2. Overview of the risk's categorisation.

Risk		Firm A	Firm B	Firm C	Risk Category
Core	Supply risk	Single source for the customer. High number of failures by initial samples	Second source available. Failures in PCBs with hard gold contacts.	Single Source. Possible risk by the outsourcing of the grinding process	Major Risk
	Operational risk	Measurement equipments are at state of the art. However they should get actualise in the coming year. An ERP system is not available.	High employee fluctuation. A qualified employee left the firm leaving the tasks unfinished	Increasing digitalisation tasks in the firm. Risk of overrunning tasks.	Medium risk
	Demand risk	Demand increased by approximately 20%	Demand decreased by approximately 20%. Trying to increase businesses.	New business of a new product. No forecasts are available.	Minor risk
External	Finance risk	Private Ltd firm. Monitor the continuity of descendants.	Ltd. with stock exchange. Firm is located in a Special Economic Zone Seepz (tax free zone)	Pvt Ltd.	Minor risk
	External risk	Possible currency devaluation (approx. exchange rate 82.65 Rupees-Euro). Non EU custom issues: wrong fulfilled custom paperwork documents (quantity, price of delivered parts)	Increase costs of raw material	Global political instability	Minor risk
	Cultural risk	The manufacturing process changed without informing the customer	Bidirectional open communication missing	Bidirectional open communication missing	Medium risk
	CSR risk	Standards for occupational health in India differs from Europe. Ventilation system for impregnation activities must improved.	Monitoring origin of REACH/ROHS substances like gold, tantalum, etc.	Pick up service of employees to ensure they come work	Minor risk
Infrastructure	Time risk	Delays due to custom restrictions, burocracy, quality failures and logistics distance	Delays due to custom restrictions	Delays due to custom restrictions	Medium risk
	Information risk	Product changes may not communicated.	A PCN from supplier was not notified. Forecasts missing. Payment delays.	A PCN from customer was not notified	Medium risk

Source: Case study.

Table 3. Example of a request from the German custom authorities.

	T1 TRANSIT PROCEDURES
Customs clearance	Chargeable, EUR 45,00 per shipment plus 19%VAT
We require: [x] a detailed description of the content of the delivery.	
[ ] a legible invoice.	
[ ] a preference in the original.	
[x] Other: Article not in WTN list.	
We optionally ask for registration of the following special properties of the goods. In individual cases, additional information can be required.	Authorisation number. Authorised recipient Customs office of destination
[ ]Return goods [ ] luggage [ ] samples [ ]Moving goods [ ] consignment for private purposes	**OR** Your carrier (company, address)

Source: Case study and DHL (and) (2019).

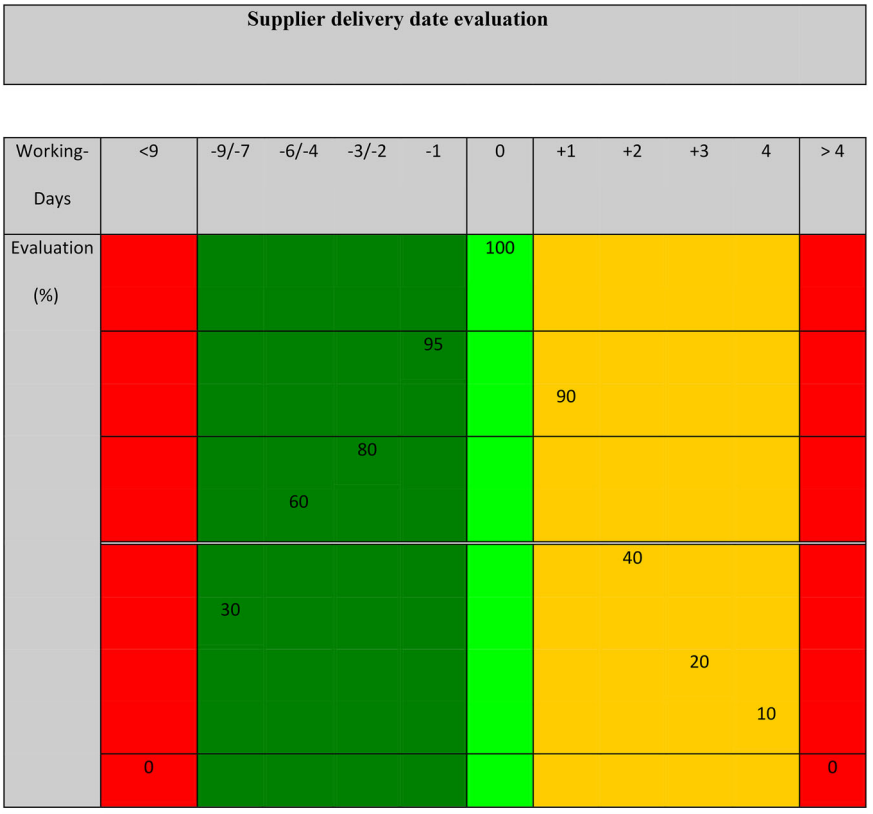
that any delay by your sub-suppliers is entirely the responsibility of you as the supplier, and you should take appropriate precautionary measures for such scenarios which could occur any time and cannot be qualified as a 'Force Majeure'. Finally, Option 4 reminds the supplier that an allocation issue does not remove its obligations towards us on basis of our contractual relationship.

Representatives of two of the three Indian audited suppliers visited the final customer in Germany in December 2019. A telephone conference was arranged with the other supplier in December, as his visit to Germany was planned for the following year. One of the major delays identified in the case studies is caused by parts being retained at the German custom authorities because of missing clearance or because the authorities found some deviations between the customer order information and the delivery document information. Thus, customer and supplier were requested to update the parts information correctly. Because of communication problems, the final customer had to get involved to try to speed up the process as the customer confirmed delivery date was delayed. In order to evaluate individual risk events, an FMEA tool based on the risk matrix criteria outlined in Figure 4-2 is applied. An example of evaluation performed in the case study is shown in Table 4.

6. Discussion, conclusion, limitations and future research

6.1. Discussion

Global logistics providers use local expertise to understand diverse customs regulations. Common terminology and import regulations and legislations must be understood as valid goods descriptions are vital to ensuring customers' shipments are facilitated smoothly via the Import Control System (ICS). This will minimise the chance of the shipment being selected for an ICS Inspection. A list of examples of insufficient description and acceptable alternatives can be verified in the case study. All shipments, with the exception of documents, being exported from/imported into China will require a Harmonised System code (HS code) to be indicated on customs declaration forms. The provision of the HS code, along with an accurate and detailed goods description in the supporting documents, will help expedite HS classification and ultimately, clearance of the goods. Based on the findings of the case study, the authors dynamically readapt the initial conceptual framework according to the feedback received from the case studies. In particular, the authors adapt and extend the



Source: Case study

Figure 3. New KPI for the supplier delivery date evaluation.
Annex: Figure 4-1. Conceptual model.

original risks defined by Quang and Hara (2018) with CSR and cultural risks. Besides their statement that core risks have a direct effect on supply chain performance, external risks like Coronavirus can also impact directly to the supply chain performance. This research study supports the findings of Medina Serrano et al. (2020) that during the period 2020-2021 the COVID-19 pandemic restrictions led to a negative impact on logistics performance, including allocations and even shortages in the supply chain. Besides the COVID-19 risk event, the year 2021 started with new risk events caused by the increased demand for certain semiconductors and electronic components, which are mainly manufactured in China and Taiwan. Whereas El Baz and Ruel (2021) investigated the role of supply chain risk management in mitigating the effects of disruption impacts on the supply chain, this research is aligned with their results about the need to have a successful organisation with a combination of dynamic resources to face shortages uncertainty. Research results aim to be aligned with the statements of Solgi et al. (2021) even though they did not take into account pandemic risks. They highlighted the relevance of selecting expedient suppliers for complex products. Indeed, our research findings confirm the importance of not only

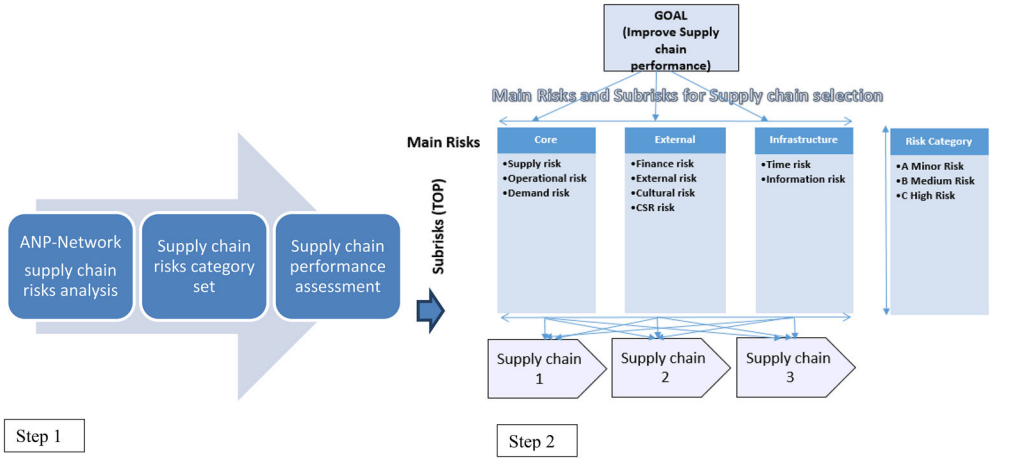


Figure 4 -2. Conceptual model.

selecting resilient suppliers, but building resilience within firms and dynamic capabilities. As mentioned by Kim (2021), and verified through a set of consultations in an in-firm case study, a shortage in production capacity compared to demand in semiconductors increased the prices of some components in 2021 by approximately 8% and they are expected to continue increasing during the Q3-Q4 of the year 2021. The availability of some parts for the coming months will be critical, which can lead to disruptions in manufacturing processes, affecting the whole supply chain.

6.2. Conclusion

The proposed model, verified through a case study, aims to analyse possible risks, classify them, create an action plan and re-evaluate them in order to prevent and mitigate risk events in logistics to reduce supply chain uncertainty.

One of our main findings is the importance of analysing the degree of supply chain risk events in order to determine the flexibility required to mitigate risk effects and reduce supply chain uncertainty. A change to the balance and profitability of the supply chain caused by potential and unpredictable events (e.g. an unexpected order, late delivery from a supplier or a breakdown of critical production equipment) can be mitigated by performing a proper supply chain risk analysis and defining the appropriate level of flexibility required so that a response to re-establish balance is planned. In contrast to the previous supply chain risk definition of Tang and Tomlin (2016), mainly: supply cost, supply commitment, process and demand risks, this research proposes matching their defined category within the definition of Table 2 as follows: supply cost risk is part of the supply risk; supply commitment risk belongs to information risk; process risk is an operational risk; and demand risk keeps the same terminology. During the interviews with practitioners it was observed that firms can obtain most of the benefits at low levels of flexibility by choosing the correct supplier. Thus, firms investing in risk reduction programs and having data scientist employees and business information systems have an advantage to mitigate future supply chain disruption effects and to reduce supply chain uncertainties.

Table 4. FMEA tool.

Potentinoteal risk	Probability	Impact	RPN	possible corrective actions for risk mitigation
Dependency: Single source: Business exit	10	32	320	**Qualify alternative supplier**
Production downtime	8	16	128	**Build second source** **Safety stock** **Schedule resources (emergency management)**
Callback actions	8	16	128	**Liability insurance** **Traceability** **Compensation Agreement**
Delivery delay> 30% or delivery stop	8	16	128	**Build second source** **Safety stock** **Schedule resources (emergency management)**
No product liability	4	32	128	**Insurance for product liability**
Defective goods: unsafe manufacturing process (quality)	10	8	80	**Request CAPA plan** **Plan supplier audit** **Agreement of QAA**

Source: Case study.

The impact of digital technology and industry 4.0 on the ripple effect and supply chain risk analytics (Dolgui et al., 2018) is evaluated. The influence of digitalisation and artificial intelligence in supply chain performance is a clear trend. Once the minimal requirements to digitalise supply chain processes are in place, different artificial intelligence solutions can be applied in order to process data, run and monitor evaluations and automate tasks, saving costs. Thus, available data would let decision makers know exactly what to decide due to the transparency of the supply chain and the impact of possible actions, reducing supply chain uncertainty. There is a part of the research community arguing about the social responsibility of firms by implementing this technology and there is an appeal and request to judge employees' performance with the implementation of this technology. Some researchers posit that firms forgot personal relationships and ethical perspectives in this search for automation of digitalisation of data. However, this should be reasonable as employees' performance relies on other factors, besides KPIs. A fully automatic warehousing system is one of the basic trends of future intelligent logistics development, which is also identified in Wu and Ge (2019) research. Thus, firms' competitiveness increases, improving e-logistics and e-procurement and reducing supply uncertainty.

One of our findings is the extreme importance of faster deliveries in the logistics and supply network, aligned with Straubert et al. (2019), Bask et al. (2012) and Fawcett's (1992) statements, among other researchers. In a volatile world, the effect of a disruption on supply chain performance should be evaluated, especially a transportation disruption (Wilson, 2007). According to her, the impact of transportation disruption on supply chain performance is less severe for firms who design a vendor managed inventory system. From the study interviews in India, research results are aligned with the findings of Kathuria et al. (2016), in that the current Indian logistics network does not meet the country's needs. On the other hand, lean logistics focus on reducing inventory by designing regularly updated forecast data and sharing it with the supply chain. Besides the inventory's extra costs, this methodology reduces capital binding and issues led by product design changes. Besides firm-specific results, this research has largely provided a special contribution in showing the value of the qualitative efficiency evaluation method of

the case study for a comprehensive sustainability analysis of supply chains. This is important as many research directions regarding sustainability concepts are featuring a qualitative setting – and this may require complementary perspectives of data-driven results as in the research setup presented here.

In contrast to the emission oriented versus time oriented routing in the European research of Heinold and Meisel (2019), which considers only the European region, our research results suggest that it is important to evaluate the logistics transport possibilities in every case, as well as the weight of the delivered goods. For instance, delivering parts with low weight from Gurgaon, India to south Germany is more convenient by plane, as Gurgaon is far away from the seaside.

The external providers involved in this case study are based in India (Firms A, B, C), in China (Firm D), in Slovakia (Firm E) and in Germany (F, G) so that this paper can contribute to the research community evaluating logistics risks and opportunities when dealing with external providers within and outside the Eurozone. The case study validated the proposed model and verified that risk events in logistics increase supply chain uncertainty and costs in practice and introduces the managerial implications of the results, proposing the following suggestions to improve the end-to-end digital supply chain, reducing uncertainty, risks and costs.

- Build an agile supply chain strategy with rapid planning and integrated execution
- A risk event increases supply chain uncertainty and it gets multiplied when interrelated risk events occur simultaneously. This uncertainty can be reduced by managing risk events adequately, determining the degree of flexibility required to mitigate risk effects, reducing supply chain uncertainty, defining appropriate KPIs, increasing the firm's dynamic capabilities, increasing end-to-end visibility using machine learning across the supply chain and automating processes, supporting decision makers and effectively balancing demand and supply;
- Use 'lessons learned' to prevent and mitigate risk events and reduce supply chain uncertainty, so that risks can turn into opportunities to reduce supply chain costs.
- Collaborate and cooperate with final customers, suppliers and subcontractors to ensure the most accurate forecasts for final customers, suppliers and subcontractors, leveraging downstream data with real-time visibility and digital representation of the physical supply chain (Leverage end-to-end visibility).
- Manage and continuously align supply chain capabilities at each tier in the supply chain to feed operational plans, responding to changes, optimising inventory levels and working capital, so that firms can react faster to short-term demand changes.
- Reduce production and distribution costs by performing a Demand-Driven Replenishment strategy with strategic de-coupling point and buffer zone calculations, integrating intelligence strategy using Cognitive and Machine Learning.

6.3. Limitations and future research

This study has some limitations. First, the proposed model was tested in a particular case study, limiting the results to the business activities and countries of the firms interviewed. Further empirical validations would reinforce and improve the model in

future research. Second, the choice of suitable logistics providers needs to be investigated in adequate detail for countries outside the Eurozone. Criteria like speed, agility of planning, effectively balancing demand and supply, efficiency in processing transactions, security and ease of use have to be considered. Collaboration with external providers in real time across plan-to-deliver processes increases visibility in supply. Future researchers can provide further insights in machine learning by using IT solutions like SAP Integrated Business Planning. There is no doubt that 2020 and 2021 are uncertain times where the spread of disease and panic can lead to unprecedented shortages in the supply chain worldwide. Future researchers should take into account the lessons learned from the crisis to rethink and update the existing supply chain management models. For example, making comparisons with other case studies and other branches and regions.

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