Coronavirus (COVID-19): How to Secure the Supply Chain? – A Case Study

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***Abstract*— Supply chain global dependency has been arisen in the last years and supply chain managers want to know if the manufacturing purchasing managers' index and export/import dependency rate data are effective qualitative key performance indicators (KPIs) to monitor possible supply chain risk effects in a proper way. The aim of this study is to address this question performing an analysis of the current KPIs in the main affected countries in Europe (Italy) and Asia (China). After a review of the literature on Supply Chain Risk Management (SCRM) and published official statistics in China, Italy and Germany, a case study focused on a set of interviews with practitioners based on a firm located in Germany was used to generate uncaptured insights in previous research of the area. Official KPIs and firms' supplier specific KPIs like delivery performance are key to monitor possible Supply chain disruptions. Moreover, increasing regular bidirectional communication with firms' suppliers generates trust and it is one of the most critical issues which can positively influence on firm's performance. A regular follow-up of authorities' updates in terms of restrictions at local, national and international level should be considered too. This paper identifies manufacturing purchasing managers' index and export/import dependency rate data as effective qualitative KPIs to monitor possible supply chain risk effects and disruptions in a structured manner and to outline future research opportunities in the field of SCRM.**

Keywords*—Coronavirus, supply chain risk management (SCRM), supply disruptions, manufacturing purchasing managers' index, case study*

1. Introduction

Which are the supply chain effects of COVID-19? The full effect of COVID-19 on global value chains will become clearer by the end of the year 2020. However, one question of importance is how a disruption in Chinese supply of goods will affect Europe. As consequence of the current COVID-19 pandemic, many States have conducted several measures to prevent an uncontrolled outspread of the COVID-19 virus and the pandemic. In particular, many States have ordered the closure of businesses and firms, which not deemed "essential", "critical" or "systemically important" for the society. The Federal Government of Germany and the Governments of the Federal States have also conducted similar precautions. The COVID-19 pandemic and the aforementioned precautions affect not only German firms, but also foreign business Partners on which German firms rely. The Federal Government of Germany has issued several guidelines on the precautions, which are accessible under its website [1]. There is fear that the government can extend this exception state. Global effects of China's slowdown through global value chains can lead to macroeconomic consequences. India is not so much affected by the shutdown of China, but the European Union is the most affected economic zone. The supply chain implications of China nowadays are stronger than a decade ago as its infrastructures have been improved substantially, increasing the worldwide exports and reducing transport and communication costs. According to the German statistics [2], goods worth 205.7 billion euros were traded between Germany and the Republic of China in 2019 (exports and imports). The Republic of China is Germany's main trading partner. Supply chain risks have been already researched in the past [15] [16]. However, the global situation originated by the COVID-19 is a completely new event that have never seen before. Despite of the transparency of reliable data is poor, it's credible that supplied parts for the automotive sector may fall as the industry is localized in the region where the outbreak of COVID-19 occurred.

International Journal of Supply Chain Management
IJSCM, ISSN: 2050-7399 (Online), 2051-3771 (Print)

European and especially German value chains may be disrupted as many firms are depending on Chinese suppliers. In order to face and mitigate this uncertainty, this paper has the aim to collect evidences of Supply Chain Risk management implementation through the analysis of a case study in a German firm. To accomplish this target, the rest of the paper is organized as follow; after a review of some main statistics about COVID-19 and export data in section 2, the methodology of the empirical study is explained, and the main findings from a German firm are presented in section 3. Finally, discussions are outlined in section 4 and the main conclusions, the limitations and the topics related to this study, which may lead for future researches are discussed and presented in section 5.

2. Exports and Covid-19 Statistics

The COVID-19 pandemic has seriously jeopardized the value chains of many firms around the world, as globalization has caused heavy dependence on exports / imports of raw materials and components, and the pandemic is hindering or even totally preventing the merchandise traffic. Therefore, commercial data relating to Germany's main partners needs to be analyzed. In addition to this, firms should evaluate the trends how China export figures have been changing before, during and throughout this pandemic. This study identifies some figures referring to COVID-19 and how the pandemic is affecting various countries, involved in export activities. According to the German official statistics [2], Germany's major trading partners in 2019 in terms of import values are China, followed by Netherlands, USA, France, Poland and Italy. In exports are USA, ahead by France, China, Netherlands, UK and Italy the most strategic partners of Germany (Figure 1). Technical papers in economics are published several times a year by the Federal Statistical Office, which contains articles with background information and trends regarding both the results of foreign trade statistics and the methodology applied.

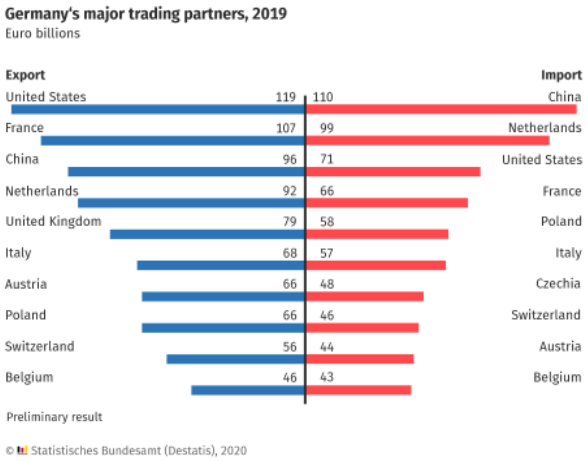

Figure 1. Germany's major trading partners. Source: Destatis [2]

According to the National Bureau of Statistics of China [3], Total value of exports in February of 2020 in China in comparison with February 2019 fell down to -17,2 % with 292,448,566 US Dollars (Figure 2).

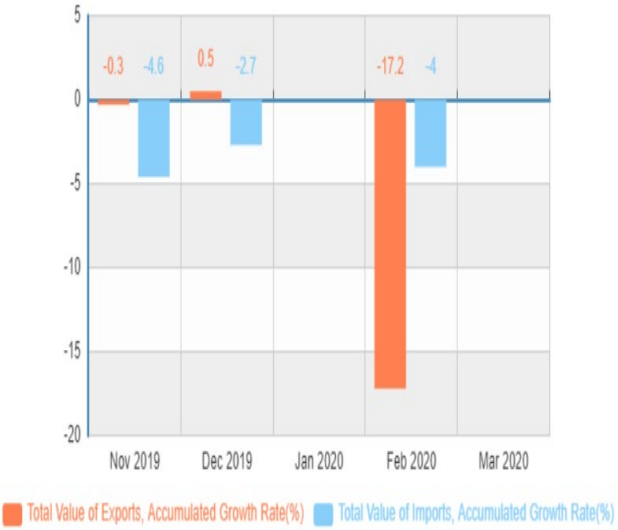

Figure 2. Overview of Chinese Imports and Exports. Source: National Bureau of Statistics of China [3]

Based on the German Federal Statistical Office [2], the export dependence rate of employment in 2016 is of 25% in Germany.

Country, Other	Total Cases	New Cases	Total Deaths	New Deaths
World	2,185,938	+4,630	146,969	+1,498
USA	678,210	+640	34,641	+24
Spain	184,948		19,315	
Italy	168,941		22,170	
France	165,027		17,920	
Germany	138,135	+437	4,093	+41
UK	103,093		13,729	
China	82,692	+351	4,632	+1,290
Iran	77,995		4,869	
Turkey	74,193		1,643	
Belgium	34,809		4,857	
Brazil	30,891	+208	1,952	+5
Canada	30,106		1,195	
Netherlands	29,214		3,315	
Russia	27,938		232	
Switzerland	26,732		1,281	
Portugal	18,841		629	
Austria	14,508	+32	410	
India	13,495	+65	448	

Figure 3. Overview Report coronavirus cases on 17-April 2020. Source: Worldometers data base [5]

According to this data base, the exports to China in February 2020 compared with February 2019 decreased by 8.9% to 6.8 billion euros, while imports from China fell by 12.0% to 7.4 billion euros. A report of the figures of coronavirus infected cases from Johns Hopkins University [4] shows that even the first country most affected by this pandemic was China at the beginning of the year 2020, along the year the situation evolved. By April 2020, from the 7 most affected countries, 5 are located in Europe, being USA the most damaged country in the world. Reports from Johns Hopkins University data base and Worldometers data base were analyzed on 17.04.2020 and it was identified that the list of main coronavirus affected countries matches in both data bases. In addition to this, the number of cases differed from both data bases which may vary by the different times of data actualization (Figure 3).

Indeed, most recent data from China indicate a substantial recover in output. China Manufacturing Purchasing Manager's Index (PMI), a critical production index, fell by about 22 points in February 2020 and surprisely recovered to 52% in March 2020 (Figure 4).

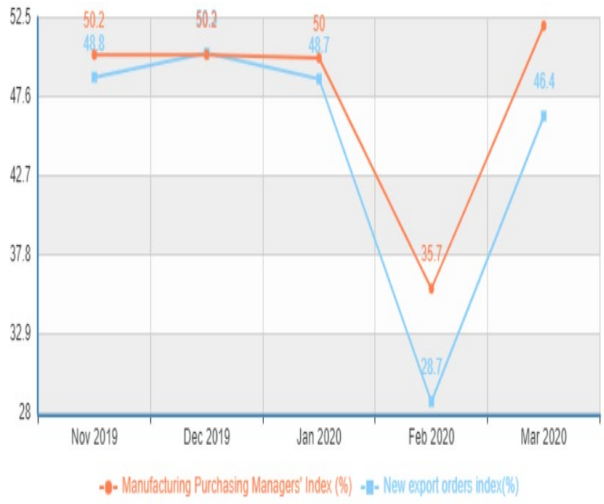

Figure 4. China's Purchasing Managers Indices in percent (%). Source: National Bureau of Statistics of China [3]

This index is highly correlated with exports and such a recover implies an increase in exports of an annualized basis. Despite of the drop observed in February 2020 spread affecting the supply of intermediate goods, indicators on March 2020 suggest a recovery in Chinese exports, which is correlated with the reduction of infected coronavirus cases in China. Whereas PMI refers to the index summarized and prepared through the monthly statistical summary of the findings of the corporate purchasing managers, New Export Orders Index refers to month-on-month (MoM) diffusion index established based on the MoM changes of the main products for export orders the firm received. PMI is one of trends index of the international common standards for monitoring macroeconomic data, with a strong prediction warning effect.

According to the OEC [6], whereas 20% of Chinese exports were shipped to USA in 2017, Germany received directly 4,5% of the total of the Chinese exports and Italy 1,3%. China is the top country by exports in the world. Exports' value in China in February 2020 reached $188,381m that accounts for 22.71% of the world's exports. Besides China, Italy is the 7th largest export economy in the world [6] and its Economic Complexity Index (ECI) available at the OEC reached the ranking of the 20th most complex economy. The ECI is a measure of the productive capabilities of large economic systems. In 2017, Italy exported $482B and imported $441B, resulting in a positive trade balance of $40.8B [6]. According to the Italian official economic data [7], Germany is the main exported country, followed by France, USA, Switzerland, UK and Spain. On the other hand, China is the third most important partner for import of goods. A ranking of main recipient countries of Italian exports in 2019 is drawn in Table 1.

Table 1. Main recipient countries of Italian exports (Ranking based on 2019 data). Source: Istat [7]

Pos.	Paese	2016		2017		2018		2019	
		mln euro	peso %	mln euro	peso %	mln euro	peso %	mln euro	peso %
1	Germania	52.703	12,6	56.043	12,5	58.179	12,5	58.113	12,2
2	Francia	44.008	10,5	46.333	10,3	48.655	10,5	49.824	10,5
3	Stati Uniti	36.888	8,8	40.433	9,0	42.406	9,1	45.584	9,6
4	Svizzera	18.966	4,5	20.575	4,6	22.328	4,8	26.028	5,5
5	Regno Unito	22.417	5,4	23.185	5,2	23.798	5,1	24.915	5,2
6	Spagna	21.054	5,0	23.260	5,2	24.200	5,2	24.027	5,0
7	Belgio	13.525	3,2	13.488	3,0	13.304	2,9	14.062	3,0
8	Polonia	11.240	2,7	12.650	2,8	13.617	2,9	13.286	2,8
9	Cina	11.057	2,6	13.489	3,0	13.127	2,8	12.993	2,7
10	Paesi Bassi	9.710	2,3	10.500	2,3	11.661	2,5	11.840	2,5
11	Austria	8.884	2,1	9.522	2,1	10.248	2,2	10.262	2,2
12	Turchia	9.599	2,3	10.112	2,3	8.780	1,9	8.334	1,8
13	Russia	6.690	1,6	7.955	1,8	7.567	1,6	7.918	1,7
14	Giappone	6.022	1,4	6.554	1,5	6.465	1,4	7.740	1,6

3. Data Collection Methods: In-Firm Case Study

To analyze how the COVID-19 pandemic affects supply chains, and how firms can face and mitigate uncertainty in this context, this study focuses on a case study. The firm under study is a leading manufacturer of electronic products based in Germany with 1.669 employees and a €275m turnover (key figures from the end of 2019). The main criteria for selection of this firm were that the firm (1) identified a need for improve the sustainable supply chain uncertainty, (2) and had recently performed supply chain risk and logistic evaluations. Furthermore, this firm has some of its main partners in India, Italy, Slovenia, Slovakia and Germany, whose partners are also indirectly under study. The case study will also be useful to analyze the ongoing mitigation actions planned by the firms involved and to identify a series of lessons learned. Additionally, a systematic literature review (SLR) was accomplished in a previous paper [8] to collect data as a basis for the interviews, structuring relations of digitalization [9] and ensuring completeness and reproducibility of the results [10]. In this previous paper, multiple strategies from the simultaneous use of supply chain management designs were outlined and are taken into account for the present case study's interviews. Besides this literature review, an empirical qualitative evaluation was required which will lead to more cross-industrial supply relations. 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 analyzing supply chain core risks in order to meet the respective customer and product needs. By applying a qualitative approach, this research work analyzes the different KPIs identified from official data bases in China, Italy and Germany.

To undertake the case study, information was collected on how the firms involved react to COVID-19 supply chain risk effects. The case study will be useful to understand whether COVID-19 related risk events increase supply chain uncertainty in the practice. Lessons learned from interviews with decision makers (purchasers, logistic and supply chain managers) are collected in order to understand the interrelation between the firms, third parties and the factors and possible outcomes of supply chain core risk events. In order to do this, a number of interviews were undertaken with decision makers from India, Italy, Slovenia, Slovakia and Germany. The interviews, their design, the analysis of the transcripts and how the findings were integrated into the research work are described here. Semi-structured interviews with decision makers were carried out and mainly covered the following topics:

- Details of the interviewee
- Areas related to the supply chain core risks
- Possible COVID-19 supply chain risk effects
- Effects of interconnected risks
- Mitigation activities to prevent shortages and disruption of the supply chain
- Alternative options to suppliers located in critical countries
- KPIs used to monitor COVID-19 supply chain risks
- Alternatives to short-time work or restrictions on production activities
- Lessons learned and suggestions from ongoing decisions

The case study was carried out using evidence from multiple sources, such as consignment stock agreements (CSA), non-disclosure agreements (NDA), confidential disclosure agreements (CDA), supplier self-disclosure forms, firm statistics like delivery performance, quality assurance agreements (QAAs), supplier audit reports, delivery contracts, suppliers' related meeting minutes, purchase orders, purchase order confirmations, supplier delivery

performance reports, regular communication transcripts, final reports, demand planning and forecasting configuration at SAP and project plans, with a view to gain validity and reliability [11]. Obviously, there is a massive trend to implement and monitor KPIs everywhere, which is lasting to a massive data to process. Contradictions about supplier evaluation criteria and their subsequently supply chain performance leads to interpret different outcomes.

3.1 Findings from the case study

The German firm required an ongoing analysis of possible COVID-19 supply chain risks effects caused by supply chain disruptions. A key input collected during the case study analyzed is the need to re-evaluate possible supply chain disruptions regularly, improving the communication all along the firm, defining the criteria for monitoring, reporting and recording. An overview of the firms involved is drawn in Table 2. Whereas Firm A's line of business is focused on machinery, including manufacturing metallic parts and precision mechanical components, Firm B and Firm E are Electronic Manufacturing Services (EMS) providers. Moreover, Firm C is a manufacturer of precision-engineered products and Firm D is a manufacturer of electrical products. Despite the difficulty to predict the exact consequences of coronavirus, this research work analyzes how the COVID-19 could impact to the supply chain in Europe. Firms might begin to see impacts across the supply chain, including resources like: (1) land; (2) labour; (3) capital; (4) energy; (5) entrepreneurship; (6) information; (7) expertise; (8) management; (9) materials; and (10) time [12].

(1) Above the ground (air and space rights), travel may be restricted to certain areas, limiting the ability to discover, qualify and certify new sourcing and transact information.

(2) Labor may not be available or partly available due to quarantine guidelines, short-time work or illness. In the same manner, Firm D decides on short-time work so that the workforce is planned to be reduced for the year 2020, reducing its resources. The firm is responding to volatilities in demand caused by the COVID-19.

(3) Customers' demand can fell down because of the uncertainty of purchasers.

(4) No activity is possible without energy.

(5) Starting new businesses, qualifying new suppliers can be limited due to the COVID-19 restrictions.

(6) Communication and consultation with suppliers should be conducted through regular meetings and documented on remote basis, proving the required information.

(7) Admittedly, Firm B has a plan for training new employees or employees from different areas in a rotation basis in order to extend the qualification of its employees.

(8) Supply networks may experience limitations in capacity and availability so that even if materials are available; they would be stuck elsewhere, limiting the logistics for the management.

(9) Supply shortages of materials or finished goods coming from or routed through COVID-19 affected areas.

(10) As an example, Firm A can reduce the lead time caused by the government restrictions, permitting the manufacturing of parts for essential businesses as specified by the government.

Table 2. Overview of the firms involved. Source: case study.

Evaluation's criteria	Firm A	Firm B	Firm C	Firm D	Firm E
Main business	Manufacturer of inductive components	Electronic Manufacturing Services (EMS) provider	Manufacturer of precision-engineered products	Manufacturer of electrical products	Electronic Manufacturing Services (EMS) provider
Country	Italy	German Subsidiary (Dutch Group)	India	Slovenia	Slovakia
Firm's size	Small-SME	Upper-SME	Upper-SME	Upper-SME	Small-SME
Number of employees	51-200	1001-5000	1001-5000	1001-5000	51-200
Turnover	€30m	$507m	$200m	108m	€12m

COVID-19 implications	Government restrictions on production activities	Short-time work.	Government restrictions on production activities	Manpower needed	Not affected yet.
Delivery time	Extended due to restrictions. Make to order	Extended due to Short-time work.	Extended due to restrictions Make to order	Extended due to missing manpower Make to order	Not affected yet. Make to stock / Frame contract available.
Certification	ISO 9001 (Manufacturing), ISO 14001 (Environment), IATF 16949 (Automotive)	ISO 9001 (Manufacturing), IATF 16949 (Automotive), ISO 13485 (Medical), ISO 14001 (Environment)	ISO 9001 (Manufacturing), IATF 16949 (Automotive), ISO 14001 (Environmental) ISO 45001 (Occupational health and safety)	ISO 9001 (Manufacturing), ISO 14001 (Environment)	ISO 9001 (Manufacturing), IATF 16949 (Automotive), ISO 45001 (Occupational Healthy), ISO 14001 (Environment)
Risk of shortage	High	Medium	High	Medium	Low

Leading supply chain organizations utilize enhanced risk management processes. In addition to this, measure KPIs like the PMIs and new export order index are preparing possible pandemic scenarios for controllable and foreseeable uncertainties such as compliance, labor, material, capacity and financial issues. One of the possible scenarios is the lack of access to staff, decreased productivity and a decrease of demand due to uncertainties. After conducting a set of consultations with practitioners, our analysis concludes that the greater the supply, demand, transportation, infrastructure and the COVID-19 pandemic risks and their link, the greater the negative impact on logistics performance and the severity of each and all risks on outputs. This is aligned with the four hypothesis validated by [13] in their research and the push effect developed by [14]. This research focuses mainly on core risks, identifying them through the case study (Table 3).

Table 3. Overview of core risks. Source: case study

Risk		Firm A	Firm B	Firm C	Risk Category
Core	Supply risk	Many parts are single source for the customer.	Second source is available for some parts.	Single Source for the customer.	Major Risk
	Operational risk	Risk of COVID-19 infected employees.	Risk of COVID-19 infected employees.	Risk of COVID-19 infected employees.	Major Risk
	Demand risk	Demand is expected to remain constant.	Demand is expected to decrease. A second source has been qualified.	New product introduced. Demand is expected to increase.	Minor risk

4. Discussion

The full impact of coronavirus on supply chains might not become obvious until sometime along the year 2020. However, decision makers should take preventive actions to mitigate supply chain risk effects and reducing the impact on their value chain. A list of lessons learned from the case study can be taken into account for decision makers, like:

- Develop a risk for supply chain disruption monitoring and response programs for countries impacted by the COVID-19 and potential supply chain exposure from suppliers. For instance, monitoring the KPIs from the data bases mentioned in section 2 and monitoring and reviewing defined KPIs from the firm's score card. KPIs are defined and integrated into firms' ERP system and official country portals. Thus, risk managers can review the past and current status of all the products and all qualified suppliers, establishing a congruent risk management approach to monitor and prepare for potential material and manufacturing capacity shortages. These uncertainties can be reduced by managing risk events adequately, determining the grade of flexibility required to

mitigate risk effects, reducing supply chain uncertainties and defining appropriate KPIs.

- Reschedule labour time in order to mitigate the spread of the COVID-19, enabling several shift works, home office and remote activities.
- Financial implications concerning customers and suppliers should be taken into account.
- A guideline and emergency plan for employees and suppliers should be created and notified accordingly. Especially, sending critical manufacturing notifications for suppliers located in the affected COVID-19 countries. For combating the COVID-19 pandemic it is of importance that all businesses and firms which are "essential", "critical" or "systemically important" for the society continue working. Such firms are in particular firms, which are active within the field of healthcare/pharmaceuticals, food manufacturing, transportation and the provision of electricity and energy. Firms, which provide products and services to customers in those sectors and require materials or parts from Italian suppliers should notify it to the Italian government so that Italian firms can receive special permission from the government to supply essential parts and components supporting customers and combating the COVID-19 pandemic. A notification about supplier mitigation plan to avoid any interruption in the supply chain should be requested.
- An inventory planning based on updated customer demand and supplier availability information should be regularly monitored. Thus, diversifying supply multiplied sources can reach a balance of supply and demand, building buffer stock.
- Possible supply chain risk scenarios should be taken into account, creating short, medium and long-term forecasts and taking into account alternative sources, inventory and cash reserves in order to mitigate major disruptions.

5. Conclusions

This crisis seems to affect mainly to Small and Middle Enterprises (SME) which can not afford the shutdown for a long period of time and it will lead to bail outs. The COVID-19 pandemic will pass, but it has served to demonstrate the dependence of the firms on their foreign partners, and the disadvantages of the globalization of their value chains. Moreover, increasing regular bidirectional communication with firms' suppliers generates trust and it is one of the most critical issues which can positively influence on firm's performance. A regular follow-up of authorities' updates in terms of restrictions at local, national and international level should be considered too. This paper identifies manufacturing purchasing managers' index and export/import dependency rate data as effective qualitative KPIs to monitor possible supply chain risk effects and disruptions in a structured manner and to outline future research opportunities in the field of SCRM. Future pandemics or other international events may jeopardize the value chains of firms, so the recommendations made here can also be extrapolated, and hopefully enriched, in future moments. Notwithstanding the above findings and contributions, this study faced a number of limitations and so do its outcomes. Firstly, a potential limitation of this study stems from the fact that our in-depth analysis focused exclusively on one case study, located in Germany. In addition, the firm object of study is a global player who identified a need to improve the supply chain risk management process, so that the firm can become a qualified object of study, and it allows the generalization of their findings with certain limitations. As a consequence, the comparison with other case studies from other regions was not evaluated. Secondly, the full impact of coronavirus on supply chains might not become obvious until sometime along the year 2020. As the coronavirus outbreak spreads rapidly and exceeds the SARS outbreak in 2003, supply chain managers must mitigate instant disruption and plan for future incidents. Thirdly, this research work focuses on core risks, based on the new COVID-19 virus. Fourthly, how is the supply chain COVID-19 response in other branches, regions and firms? Do firms find the monitorization of the analyzed KPIs understandable and useful?

However, our findings seem to provide a valuable understanding of the current situation in this research field. The present study equally suggests several future research strands which may encourage more future studies in this important area in other countries too. More qualitative research is needed to go deeper into the variety of different supply chain risks that require distinct assessment and risk strategies (avoidance, transference, acceptance, exploitation, sharing, enhancement, mitigation, etc.). In our opinion, this paper can prove useful for researchers and decision makers, since new trends and standards are emerging in SCRM that will probably lead to future research and different ways

of implementation in firms. Definitively, there is room for future researchers on SCRM field.

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