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# Improving Supply Chain Robustness & Resilience? Lessons from a case study in the automotive industry during the first wave of Covid-19

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BUSINESS  
SCHOOL

It has been presented Monday, 5 July 2021 – 1pm to 2:30pm BST

1pm

**Oral**

**New Supply Chain Models for the Covid-19 Crisis (Chair: Prof. Nathalie Fabbe-Costes)**

*Stage - Stage 1*

Chaired by: Prof. Nathalie Fabbe-Costes

**Keeping key suppliers alive during the Covid-19 pandemic:  
Artificial resilience and supplier crisis response strategies**

» Dr. Mauro Fracarolli Nunes, Dr. Camila Lee Park, Dr. Ely Paiva

**Supply chain coordination during pandemics with information  
structure consideration**

» Mr. Gurmeet Singh, Dr. Indranil Biswas

**Digital platforms: exploring the impact of COVID-19 on e-  
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» Mr. Arunpreet Sualj, Dr. Jagjit Singh Srail

**Improving Supply Chain Robustness & Resilience? Lessons from a  
case study in the automotive industry during the first wave of  
Covid-19**

» Prof. Nathalie Fabbe-Costes, Mrs. Yasmina Ziad

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# **Improving Supply Chain Robustness & Resilience? Lessons from a case study in the automotive industry during the first wave of Covid-19**

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## **Abstract**

The Covid-19 pandemic has shed light on two important but complex SCM concepts: SC robustness and resilience. This paper explores whether SC robustness and resilience should be combined and how to improve both. The research is based on an in-depth single case study at Renault Group, a global car manufacturer. Forty-three key informants involved in managing the SC during the first wave of Covid-19 shared their experience. They confirmed the usefulness of making existing SCs more robust & resilient and suggested a set of resources and practices to do so. The discussion of the results opens new research avenues.

**Keywords:** Supply chain robustness, Supply chain resilience, Qualitative case study

## **Introduction**

Efforts to improve either supply chain (SC) robustness or resilience have a common purpose: to enable the SC to cope with disruptions, risks, uncertainties, or crises. However, despite having the same objective and often being used interchangeably in the SCM literature (Christopher and Peck, 2004; Purvis et al., 2016), robustness and resilience are very different. While robustness concerns the strength and resistance necessary to ensure business continuity despite problems, changes or damages (Brandon-Jones et al., 2014; Wieland and Wallenburg, 2012), resilience involves bouncing back and rebuilding the SC after a shock or disruption (Christopher and Rutherford, 2004; Hohenstein et al., 2015; Ponomarov and Holcomb, 2009). We argue that in a complex and uncertain environment, an SC should be both robust and resilient in order to withstand the foreseeable risks inherent in the company's operations, SC and environment, and also to cope with much larger and unanticipated crises such as Covid-19. But is it possible for a company to improve both the robustness and resilience of its SC? If so, how?

To answer these questions, we first reviewed the literature to clarify what robustness and resilience mean. We also looked for previous research that investigated how to combine and improve SC robustness and resilience. Given the scarcity of literature on this subject, and taking the Covid-19 crisis as a research opportunity, a case study approach was chosen (presented in the research design section). During the first wave of

Covid-19, many companies tried to make their SC robust and maintain the continuity of their operations as long as possible. However, most of them experienced disruptions that challenged their resilience. Interested in our research question, Renault Group, a French car manufacturer, offered us the opportunity to conduct an in-depth empirical study mainly based on 43 semi-structured interviews with key informants. The findings section presents the results, structured in four main points: 1) how respondents perceived the Covid-19 crisis for the company and its SC; 2) their SCM “experiences” during the first wave and their interpretation and assessment of the robustness and resilience of their SC; 3) their view – after the first wave of Covid-19 – about whether SC robustness and resilience should be combined, and 4) from their experience of this crisis, what could be done to improve SC robustness and resilience. The discussion section returns to theoretical aspects to identify some of the contributions of this research, followed by the conclusion outlining its limitations and opportunities for future research.

## **Literature review**

### *Risks, uncertainties and crises*

Supply chains face a significant number of hazards, risks and disruptions due to their complex nature, their activities and their environment. Some of them are frequent, predictable and can be anticipated such as delays in delivery, raw material shortages or demand fluctuations (Tang, 2006). Those types of risks are well-known, and managers have to a certain extent mastered how to deal with them during their day-to-day operations and are considered “business as usual”. In the literature, it is suggested that “businesses that do not have a supply chain risk management (SCRM) in place may neglect specific risks – particularly if the frequency of occurrence is low or the nature of the risk is unique” (Wieland, 2013, p.652). However, some events, crises or phenomena are by nature unpredictable. There is a difference between risk and uncertainty (Knight, 1921).

The Covid-19 pandemic that hit the world at the end of 2019 is one of those unexpected events. During the first months of the crisis, the vulnerability of some global SCs was singled out as they were not well prepared to face this type of crisis, or the companies had not done enough risk management or SCRM. In short, the SCs were considered not robust enough. Other, less vulnerable and/or less exposed SCs resisted quite well. Nevertheless, because of its unprecedented nature in many respects, this crisis severely impacted many SCs and quickly brought home the need for SCs to be able to bounce back and recover from this disruptive event (still not finished), in other words: to be resilient.

### *Robustness versus resilience*

Robustness and resilience are two notions that are often confused and used interchangeably in the SCM literature (Christopher and Rutherford, 2004; Purvis et al., 2016), yet, in line with many studies, we consider they are very different.

Robustness is a multidisciplinary concept, often used in engineering, biology, architecture and mathematics. In the field of engineering, for example, robustness characterizes the conditions that ensure models, methods or systems function properly. Robustness is a measure of the reliability of a method or a system under routine conditions of use. In the SC context, robustness is defined as the ability to withstand or resist disruptions without the need to adapt the SC's configuration with stable performance before and after the disruptive event (Brandon-Jones et al., 2014; Klibi et al., 2010; Vlajic et al., 2012; Wieland and Wallenburg, 2012). Robustness refers to the anticipation and management of risks and aims to put in place devices (tools, skills, or rules and procedures) to prevent risks or minimize the ensuing damage.

Like robustness, resilience is also a multidisciplinary concept (Ponomarov and Holcomb, 2009). The term resilience has its origins in the physical sciences where it refers to the ability of a metal to resist pressure and return to its original structure after being distorted. Cyrulnik (1999) who applied it in psychology, defines it as the ability of humans to live, thrive, and grow despite adversity. In the SC context, resilience has been widely defined as the ability to absorb disruption, respond, quickly recover and grow from disruptive events (Christopher and Rutherford, 2004; Ponomarov and Holcomb, 2009; Hohenstein et al., 2015; Chowdhury et al., 2019). In psychology as well as in the SCM literature, it is sometimes asserted that "what doesn't kill you makes you stronger", suggesting a learning process post-disaster that could lead to a better state than before.

### *Robustness and resilience*

Given the fact that the aim of any SC is to continue operating and avoid disruption as much as possible considering the financial losses that it can cause, robustness seems a necessary SC capability to develop. Nevertheless, building a robust SC is not enough because the SC may have to face unforeseen dangers or events, such as a violent storm, a tsunami, a catastrophe, or a pandemic. Thus, considering that an SC should be prepared to operate in a VUCA world, we argue that companies must improve both the robustness and resilience of their SC in order to face future known and unknown risks and crises.

Many papers have studied SC robustness or resilience separately, but very few have focused on the two in combination. Although more recent work (Brandon-Jones et al., 2014; Adenso-Díaz et al., 2018; Thomas and Mahanty, 2019; Li and Zobel, 2020) attempts to clarify their relationship, questions remain about whether it is possible to combine SC robustness and resilience and how to do so. Some authors highlight the importance of communication and cooperation in SCs (Wieland and Wallenburg, 2013), innovation (Kwak et al., 2018), as well as information sharing, connectivity and visibility (Brandon-Jones et al., 2014) to improve the resilience and robustness of SCs. Nevertheless, Brandon-Jones et al. (2014) identify a possible dilemma between the two that depends on investment choices (which are closely related to strategic choices): robustness is best suited to SCs whose primary concern is reliability, while resilience may be better suited to SCs that struggle with speed and flexibility. Li and Zobel (2020) also highlight the dilemma between investments that promote robustness in SCs and others that promote resilience. Thomas and Mahanty (2019), who have conducted simulation-based research, conclude however that while robustness and resilience are two "desirable qualities of SC" (ibid., p.741), there are conflicting performances and companies need to find a suitable balance between them. This result has also been highlighted by Spiegler et al. (2012) for whom robustness and resilience cannot be achieved simultaneously. These authors insist on the importance of particular industry characteristics.

While the body of knowledge about robustness and resilience has grown substantially but separately in the field of SCM, the literature that has studied both robustness and resilience is still nascent. Specifically, how to improve both capabilities is a promising, yet underexplored research area. Accordingly, to close this gap our objective is to find answers to the following research questions: RQ1 – whether SC robustness & resilience should be combined; RQ2 – how SC robustness & resilience could be improved.

### **Design/methodology/approach**

As mentioned in the introduction, this research is based on a single qualitative case study (Gammelgaard, 2017), conducted after the first wave of Covid-19. The company that offered us the opportunity to do the case study (Renault Group) is a large French car manufacturer known for its robustness and resilience during the various crises it has gone

through. The company wanted to learn from the experience gained from the Covid-19 first wave and was convinced that using the conceptual lenses of robustness and resilience was useful. During a kick-off conference on the 8<sup>th</sup> of October 2020 we presented the research project, the main concepts (risk, uncertainty, robustness and resilience), a summary of existing research, the expected outputs of the research for industry and academia, and talked with the audience (approximately 90 persons attended the meeting).

We had several meetings with the company to prepare the data collection phase and then conducted 43 semi-structured interviews between October and December 2020. As detailed in Tables 1 and 2 (in the Appendix), we interviewed various directors and SC managers chosen because of their position in the company, in the SC department, their area of SCM responsibility, and for other departments, their relationship with SCM and SC operations. We deliberately focused on persons “concerned” by SCM during the Covid-19 first wave, but with different hierarchical levels and different viewpoints. A majority of respondents are in the SC department, but it was important to include other functions, some participating in the management of the SC, while others are more involved in its support (human resources (HR), IT, quality, etc.). The respondents have a high level of seniority in the company (averaging more than 20 years of experience) but with an average of 2.5 years in the position they had during the Covid-19 first wave (some having changed since then). Because of the pandemic and the restrictions in France during the period October-December 2020, 20 interviews were done face-to-face on site, while others were done remotely using Teams. During this period, we also collected internal documents to better understand the SC and its management.

We adopted an interpretivist approach (Darby et al., 2019) to conduct the research. To avoid bias from both researchers and respondents, we decided to give them our definitions of SC robustness and resilience during the kick-off conference. For the persons who did not attend, we gave a brief presentation at the beginning of the interview to clarify the concepts and the objectives of the research. During the interview, we asked respondents what these concepts meant for their SC: agreement/disagreement with our definitions, competing definitions or complements. With this basis, we were able to interpret their answers to the research questions. The interview guide comprised two sections. Section 1 addressed the following themes: respondents' perception of SC robustness and resilience, SC risk management (SCRM) in their organization and the management of the Covid-19 crisis in their company and SC. Section 2 focused on learning from the first wave of Covid-19 about combining and improving SC robustness and resilience.

All interviews (identified by their number [X] – see Appendix) were done by one of the researchers (the same for all interviews) and were recorded. Transcripts of interviews were made by the interviewer using NVIVO. The first coding of all interviews was done by the other researcher to have an outsider perspective of the collected data. In this paper we present the results from this first coding, bearing in mind that the double-coding is still in progress. We will present the final results during the conference. The coding uses pre-established codes (from the literature review, mainly about concept definitions) and open coding to capture “interesting points” (in our opinion, in relation to the literature) about SC management during the Covid-19 crisis, the utility of combining SC robustness & resilience (RQ1), and the practices that, according to respondents, might be implemented to improve SC robustness & resilience (RQ2) as well as any suggestions they might make based on lessons gained from the Covid-19 first wave experience.

## **Findings**

Most respondents (35 out of 43) consider they had an active role in managing the first wave of the Covid-19 crisis. Many of them had a direct role in management of the SC

with a mix of “operational people” running the operations and others more involved in monitoring them, partly remotely due to homeworking. Others were “supporting” SC activities, providing IT solutions, solving HR questions, and sharing expertise. The variety of respondents’ positions, departments and SC scope, together with the variety of countries in the world they represent, provides a rich picture of this crisis management, their perceptions of SC management during this period and what they learned from the experience. This is all the more important as the company is a worldwide manufacturer, with assembly plants in many countries and regions, as well as multinational supplier and dealer networks. Even though there is a regional SC logic (coherent with plant locations), inbound and outbound flows are complex. The topology of the SC and its management are complex with a clear focus on cost reduction in order to offer cars with a competitive price-quality ratio. As mentioned in the introduction, the most important results from our analysis of the data are structured in four points.

*Covid-19: just another crisis, but very different from others in nature and magnitude*

The majority of interviewees mentioned that Covid-19 is not the first crisis the company and its SC have experienced. They spontaneously mentioned many crises. The most cited were: Fukushima, the 2008 financial crisis, the destruction of a supplier plant, snow storms or major strikes. The list reveals a wide variety of crises: natural disasters; financial, political, geopolitical crises; as well as social or technical internal crises. Most respondents expressed the feeling that crises are becoming more frequent, more complex to manage, and with greater impacts on the SC and the company. Some of them (e.g. [4], [14]) used the acronym VUCA to qualify today’s world.

Having gone through several crises in the last decades, they declared they are used to crises and that crisis management is in their DNA. Thirty-three respondents spontaneously added that the company and the SC department have a reputation for being good at managing crises. SC respondents confirmed: “we are good firemen!” ([1], [7], [9], [22], [27], [34], [41]). Facing disruptive events is therefore “routine” for them and the Covid-19 crisis was initially perceived as just another crisis to cope with.

However, most declared that it is *not* a usual crisis for them (as individuals working in this company), for the company, its SC and the automotive sector as a whole. The Covid-19 crisis is global ([1], [14], [23]), systemic [34], extraordinary in terms of duration [1], with an unprecedented severity [4], [5], [17]. Covid-19 was “an unforeseeable crisis” ([6], [14], [27]), “we never had that before” ([14], [34]).

*First objective: to be as robust as possible; then resilient*

When facing the beginning of the first wave of Covid-19 in early January, because some of the company's suppliers are based in Wuhan (China), most respondents said they focused on “resisting” and “maintaining the SC as robust as possible as long as necessary” (thought not to be too long). They said they had learned from other crises [29], in particular from the Fukushima crisis (e.g. [15], [16], [21], [26], [33]), on how to deal with shortages and had solutions to deploy. The objective was to continue to supply assembly plants worldwide and to deliver to clients on time. Operational SC performance was the proof of the SC's robustness. But it quickly appeared that Covid-19 was a different crisis, spreading worldwide with unexpected effects and issues.

Most respondents mentioned that they quickly understood that for such a crisis the readymade solutions could not prevent disruptions. “It was obvious that off-the-shelf solutions would not be sufficient” [21], the same for “usual processes” [33]. Having gone through several crises in the last decades, the company had developed crisis management and rapid response capabilities (e.g. there are shortage managers whose job is to find

solutions quickly). Respondents mentioned that individuals, teams and departments combined ready-made answers (from SCRM and crisis experiences) and creative solutions. They speeded up the pace of decision-making, fostered the development of new SC visibility and decision-making tools and used existing tools (e.g. S&OP) in an innovative way. For some respondents (e.g. [4], [21], [29]), SC resilience calls for “creativity”, “to re-invent” ways of working in the company [12] and with suppliers and clients (e.g. [20], [23], [24]).

But, as the pandemic was spreading, as stated by [17], “Given the magnitude of this crisis, robustness was a losing battle!” The shock, seen by respondents as the major event or the “disruption” from a logistics and SCM perspective, was the lock-down decision taken in the countries where the company operates, in particular in China, Italy, Spain and France. It was the first time in the company's history that they had to close manufacturing plants outside of the planned summer maintenance season [29]. The management of flows before shutting down and the preparation for reopening was seen by respondents as a test of resilience for the SC and its management [30]. The narratives explaining how they succeeded in managing this period refer to increased information sharing in the company and with suppliers [23] and clients [24] – with more transparency – ([25], [37]), intense vertical and horizontal collaboration ([7], [9], [11], [15], [23], [27]), elaboration of multiple scenarios with frequent updates ([8], [15], [18], [21], [22], [23], [41]), testing of new SC options never tried before (e.g. to find transport solutions), new ways of using the available data and finding new data. According to the majority of respondents, everything ran as smoothly as possible. Recovery operations after the first wave were considered an SC success by most respondents, even by those who do not work in the SC department. This is probably why, except for five respondents ([32], [35], [37], [41], [42]), “it was a shock, not a trauma”.

#### *About perceived SC robustness and resilience and the answer to RQ1*

For most interviewees, at the time when they were interviewed, the SC proved to be both robust and resilient, and most of them considered that the SC had “done the job” ([5], [40]), in particular to shut down and restart operations in assembly plants worldwide. Most respondents agreed: an SC should be robust & resilient, which for most of them is not contradictory. Thirty-eight respondents considered that SC robustness and resilience are both necessary to face shocks. However, nine respondents considered there are trade-offs to consider when combining SC robustness and resilience. In the context of our case study, they are considered as different but valuable SC capabilities to combine.

Robustness, combining anticipation thanks to SCRM with quick responses and emergency reflexes is the most efficient way to absorb anticipated risks, normal fluctuations and “usual” crises. For 41 respondents, the SC can be prepared to be more robust, in particular when facing anticipated hazards and risks (for 37 respondents). For the majority, robustness consists in finding ways, at the organizational level, to ensure continuity of flows and operations (31 out of 43), to resist (27 out of 43) and to deliver the expected performance (22 out of 43). For 23 respondents, robustness can be formalized with processes, standards, tools, and improved with TQM practices, etc. But, as mentioned by many respondents, you cannot anticipate every risk ([12], [14], [18], [33]), some events will remain unforeseeable and impossible to prepare for ([17], [18]), and it is too costly to safeguard an SC against all possible risks ([13], [18], [34]). Some respondents (e.g. [34]) compared SCRM with insurance choices.

Since you cannot plan for everything, the majority of respondents consider that disruptions will happen and therefore an SC must also be resilient. For many respondents, resilience is less clear than robustness, probably because the automotive sector and the



company are more robustness-oriented [27]. For 37 respondents, resilience refers to the SC's ability to face a disruption, to rebound and to recover. According to 19 respondents, this capability mainly relies on the resilience of individuals and teams. For 25 respondents, resilience concerns unexpected, surprising, extreme shocks, and 23 considered that it is only when facing such shocks that you know whether an SC is resilient. Thirty-six respondents consider that SC resilience does not necessarily mean returning to the initial stage. For 34 respondents, an experience of resilience led them to make changes to the SC, to transform the SC. Twenty-two considered that it is necessary to learn from this kind of experience and 17 that the SC may even come out of it stronger than before. Eleven argued that it is possible to a certain extent to prepare an SC to be more resilient.

The respondents made a clear distinction between SC robustness and resilience, and some of them spontaneously mentioned some relationships between the two. Perhaps in line with the Covid-19 first wave experience, 17 respondents clearly introduced the dimension of time: first, an SC should try to be robust. If this is not possible (because the crisis goes beyond provisions or was unexpected, or the SC cannot absorb the shock), then comes the resilience challenge. Eleven respondents considered that the experience of SC resilience during a crisis provides the opportunity to improve SC robustness for the next crisis.

*About how to improve SC robustness and resilience: answer to RQ2*

Thirty-six respondents confirmed that it is possible to improve both robustness and resilience and 32 gave explicit suggestions on how to do so. During the interviews, respondents not only answered the question “could you suggest practices that might improve both SC robustness and resilience”, but they also discussed perceived vulnerabilities of the SC during the Covid-19 first wave. In addition, they spontaneously tried to think about changes which could make the SC more robust and resilient. Answers to RQ2 emerged from these three sets of data. We structured their answers, bearing in mind that they are synergetic (systemic and holistic view [4], [12]).

- SC topology is an important point raised by respondents. This includes upstream and downstream network design; the number and location of plants, suppliers and dealers; the alternative options in the networks to avoid dependence (e.g. multi-sourcing).
- SC processes is another key issue for SC robustness and resilience: flexibility, the different scenarios anticipated to react to future problems, and modularity so they can be easily and quickly reorganized.
- SCM decision-making processes also appeared to be critical in the Covid-19 crisis. It is important to give managers scanning capabilities to decipher weak signals and anticipate changes or shocks, to maintain decision-making capabilities available (e.g. shortage managers) and to be able to speed up decision-making loops.
- SCM tools are key resources for SC robustness and resilience. The key points are the SC visibility they offer (e.g. control tower functionalities); the SC mapping they provide (e.g. the available inventories of parts worldwide); and their use in simulation mode to test different scenarios. Another point is their scalability [38]. The quality of data used by tools has been raised as a critical success factor for SC robustness and resilience.
- An important issue in the Covid-19 crisis first wave was related to human resources, management and leadership. As mentioned, both SC robustness and resilience (even more so) rely on people, their expertise, and their mindset. The cohesion of

teams is important, as is the ability of managers to mobilize them. The ability to remove barriers between departments horizontally and vertically is a key issue.

- Another issue was pinpointed by some respondents: relationship management and collaboration with suppliers and clients, including helping them to improve their own SC's robustness and resilience; the need to improve the transparency of information sharing to solve problems.

Fifteen respondents clearly considered that the improvement of SC robustness and resilience requires work at different levels and that some levels are more critical for robustness (e.g. processes), others for resilience (e.g. individuals, teams).

## **Discussion**

We return to the literature to identify some of the theoretical contributions of this research. The main theoretical contributions are: to enrich the literature on combining SC robustness and resilience; to clarify the relationship between the two; to develop knowledge on how to improve both robustness and resilience of SCs.

Based on our review of the SC robustness and resilience literature, we chose to make a clear distinction between the two. This appears to be the right choice in light of our case study. However, our findings also confirmed the complexity of the two notions, especially SC resilience. The many other notions that were used by respondents while trying to redefine the two concepts (such as agility, flexibility, rigidity), suggest that we need clear definitions before any research work or consulting action.

The answer to RQ1, about whether SC robustness and resilience should be combined, is clear. SCs should be made both robust and resilient. The case study suggests that SC robustness and resilience can be mixed (at the same time) and reinforce each other (sequentially). Our analysis of what respondents experienced in terms of robustness and resilience of their company's SC, the relationships between the two and the difficulties they encountered in attempting to maintain robustness and/or to be resilient, suggest that SC management needs to be able to quickly switch between different modes: cruising speed or crisis management (also at variable speeds) depending on current conditions. We suggest that SCM should be prepared to “navigate” in the Wieland (2013) matrix.

Some previous research has studied the antecedents of SC robustness and resilience. But these antecedents (in particular, SC visibility, collaboration, transparency, leadership, creativity) have often been “tested” one at a time in separate studies. The answer to RQ2 underlines the need to combine multiple intertwined “antecedents” operating at different levels of the SC and its management. These antecedents are a mix of resources (e.g. HR, IT tools, inventories, partners), practices (e.g. TQM, RETEX, training) and SC choices (e.g. network design, topology). The relationships between them suggest the need to adopt a systemic perspective and multiple units of analysis (UA) in research design to deepen our understanding of mechanisms. The UAs are in line with Fabbe-Costes et al. (2014) and a key UA is the individual.

From a methodological point of view, the interviews revealed the usefulness of using the robustness and resilience conceptual lenses to study an event like Covid-19 and the company's response to the crisis at the SC level. This forced respondents to be reflexive and to interpret what happened, questioning the experience rather than telling the story in a narrative way. Giving respondents clear but non-exhaustive definitions of the concepts forced them to position themselves in relation to the concepts. Since most of them agreed with the given definitions, this improved the quality and reliability of the collected data concerning the research questions (is it beneficial to combine SC robustness and resilience, can we improve both SC robustness and resilience and how?).

## Conclusion

Beyond the theoretical contributions raised in the discussion section, this research has managerial implications. It provides managers with a better understanding of what SC robustness and resilience are, why it is useful to combine them and provides food for thought on how to improve SC robustness & resilience to face complex, risky and uncertain environments subject to an increasing variety of crises (health, economic, environmental). This study gives us a better understanding of the complexity and dynamics of SC management during a crisis that involves multiples actors in the company and in the SC. It sheds light on the importance of management and leadership for the SC to be robust and/or resilient. It suggests that managers need to be careful during the transition period between trying to stay robust and trying to be resilient, which is also an important question for future research.

Our research has some limitations. It is a unique case study. Although we accessed internal data in the company concerning what happened during the first wave, it is not a longitudinal study with observations. The results rely on the respondents' *ex post* analysis. However, we consider that as the interviews were done during October-December, the first wave was “fresh” enough in their memory to avoid *ex post* rationalization. Since, like many others, the company has faced new crisis episodes after the first wave (blockage of the Suez Canal, shortage of electronic components, other Covid-19 waves), we could make a second round of interviews to analyse the evolution of perceptions, experiences and knowledge about SC robustness & resilience. Since we only interviewed people inside the company, we could expand our data collection to external SC partners to compare their interpretations, experience and vision regarding the RQs.

In the perspective of middle-range theorizing (Darby et al., 2019), our results could serve as a basis to conduct multiple case studies with other worldwide assembly / manufacturing companies facing similar contexts in other sectors.

Covid-19 is considered to be an unprecedented crisis. Like the terrorist risk revealed by the September 11 2001 terror attacks (Christopher and Peck, 2004), Covid-19 has revealed the pandemic risk and its huge impact on SCs and the global economy. Most risk managers and SCRM researchers now will include pandemics in their scanning agenda and their risk list. At the time of writing (April 2021), Covid-19 and its effects on the economy and geopolitics looks more like a mega-crisis with irreversible long-term effects. In this highly uncertain future, SC robustness & resilience are more than ever a strategic issue for industry and research.

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## Appendix

Table 1 – Type of interviewees according to their status in the company and their department

Department	Position	Senior Vice President (SVP)	Vice President (VP)	General Manager (GM)	Manager	Expert	Operational Function /Other key informants	Total
Logistics; Supply chain Alliance (SC department)		[4]	[1]; [32]; [33];	[5]; [6]; [14]; [20]; [22]; [25]; [27]	[7]; [9]; [12]; [13]; [16]; [17]; [23]; [28]; [31]; [34]; [35];	[2]; [8]; [10]; [19]; [21]; [30]	[3]; [18]; [24]; [26]; [29]; [36]; [43]	35
Purchasing, Distribution (participating in SCM)		[37]	[42]	None	[39]	None	None	3
HR; Quality; IT; Management Control; Group Prevention and Protection (non-SCM)		None	None	[15]	[38]; [40]; [41]	[11]	None	5
Total		2	4	8	15	7	7	43

Table 2 – Type of SC interviewees according to their supply chain and geographical scope

Geographical scope/ SC scope	Regions			Country			Total	
	Europe	AMI-Pacific	Eurasia	All areas	France	Japan		Russia
Inbound	[36]			[3]; [5]; [8]; [9]; [10]; [12]; [14]; [16]; [18]; [21]; [25]; [27]; [29]; [31]; [32]; [33]; [37]; [39]		[13]		20
Outbound	[1], [34]	[20]		[2]; [26]; [42]				6
Business development				[7]; [17]; [19]; [22]; [24]; [30]; [43]				7
Plant logistics					[35]			1
Complete SC	[23]		[6]	[4]			[28]	4
Total	4	1	1	29	1	1	1	38

Note (1): In this table, non-SCM interviewees ([11], [15]; [38]; [40]; [41]) are not included.

Note (2): AMI-Pacific includes Africa, the Middle East, India and the Pacific regions.