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The role of collaboration in supply chain resilience

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Abstract

Purpose – This paper aims to explore how collaboration influences supply chain resilience. Collaborative activities and their underlying mechanisms in relation to visibility, velocity and flexibility are investigated.

Design/methodology/approach – An exploratory case study consisting of eight buyer–supplier relationships in the food processing industry was conducted.

Findings – Key findings show how specific collaborative activities (information-sharing, collaborative communication, mutually created knowledge and joint relationship efforts) increase supply chain resilience via increased visibility, velocity and flexibility. Underlying mechanisms and interdependencies of these factors within the supply chain network are identified.

Originality/value – This is one of the first papers to provide in-depth insights into collaboration as a formative element of resilience in a supply chain setting. A series of propositions explain the specific influence of collaborative activities on supply chain resilience beyond a single company perspective.

Keywords Disruptions, Collaboration, Buyer–supplier relationships, Supply chain resilience

Paper type Case study

Introduction

In today's complex business environment that calls for lean and global yet flexible operations, companies are more than ever vulnerable (i.e. at risk) to supply chain disruptions (Blackhurst *et al.*, 2011; Christopher and Peck, 2004; Pettit *et al.*, 2013). In 2013, 75 per cent of companies experienced at least one disruption, of which 21 per cent suffered more than €1 million in costs for a single incident ranging from equipment malfunctions, unforeseen discontinuities in supply, information technology breakdowns to natural hazards and disasters (Business Continuity Institute, 2013). Hence, supply chain resilience, a concept that reduces the impact of a disruption by proactively identifying strategies that allow the supply chain to react while recovering to its original or an even better functional state (Jüttner and Maklan, 2011), is of increasing interest to organizations. This requires an organization to look into the whole supply network's capabilities to survive, adapt and grow when confronted with change and uncertainty (Knemeyer *et al.*, 2009). Accordingly, the empirical and conceptual literature highlights the importance of collaboration for building a resilient supply chain (Christopher and Peck, 2004; Jüttner and Maklan, 2011; Pettit *et al.*, 2013) as the "glue that holds supply chain organizations together in a crisis" (Richey, 2009, p. 623). However, while there is an agreement in the literature that collaboration is one of the formative elements of a resilient supply chain, to date, little is known on how exactly collaboration influences supply chain resilience.

Collaboration in a supply chain relates to the capability of two or more autonomous firms to work effectively together, planning and executing supply chain operations toward common goals (Cao *et al.*, 2010). Although collaboration between organizations is the core notion of *supply chain* risk management practices, the literature on supply chain resilience lacks empirical insights beyond the single company perspective. As most supply chain disruptions (58 per cent) occur at the first-tier supplier (Business Continuity Institute, 2013) and the fact that "suppliers are the companies number one worry" in terms of risk sources (Blackhurst *et al.*, 2011, p. 382), buyer–supplier collaboration is of particular interest for investigations on supply chain resilience (Christopher and Peck, 2004; Christopher *et al.*, 2011; Jüttner and Maklan, 2011; Kleindorfer and Saad, 2005; Peck, 2005). By investigating multiple cases of buyer–supplier relationships, we aim to explore how underlying collaborative activities between supply chain members can lead to a resilient supply chain.

In answering the research question, we make three key contributions. First, although there are many papers that contribute to the body of literature on supply chain resilience by developing conceptual models, empirical research on the topic still remains scarce. Our research is one of the first studies to analyze supply chain resilience beyond a single

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company perspective. By providing insights not only on the focal company but also their suppliers and the interaction between different supply chain members, we are able to extend conceptual supply chain resilience theory to an empirical supply chain level. Second, this study sheds further light on the role of collaboration in building resilience. While collaboration has been recognized as a formative element of supply chain resilience throughout the literature, our findings identify it to be an antecedent of the constructs of resilience. We provide details on the specific collaborative activities that underlie the other supply chain resilience elements and show how they interact. Furthermore, the identified underlying mechanisms of collaborative activities that lead to a resilient supply chain also add important insights for practitioners, as they can guide decisions on relationship management for resilient supply chains. This establishes a bridge between our theoretical findings on supply chain resilience and their implications for practice.

The article is organized as follows. First, we review the literature in relation to supply chain resilience and collaboration in buyer–supplier relationships. This will be followed by a description of our case study design. Afterward, we present our findings and discuss them in relation to the existing literature on supply chain resilience. Finally, we will conclude with implications for theory and management practices, present limitations and identify suggestions for future research.

Theoretical background

Supply chain resilience

Disruptions in the supply chain can be related to any potential or actual disturbance to the flow of goods, material and/or services (Craighead *et al.*, 2007). Organizations engage in traditional supply chain risk management (e.g. identification and quantification of risk sources) to reduce the probability of disruption occurrences (Ponomarov and Holcomb, 2009) using methods such as interpretive structural modeling, analytical hierarchy process or fault tree and event tree analysis (Fowler and Sorgard, 2000; Wu *et al.*, 2006; Faisal *et al.*, 2006; Schoenherr *et al.*, 2008). At the same time, disruptions have been recognized as inevitable events in today's turbulent business environment (Skipper and Hanna, 2009): an organization can try to mitigate some risks via traditional supply chain risk management but cannot prevent all disruptions from happening. Therefore, the proactive and holistic approach of supply chain resilience that builds the adaptive capacity to be able to deal with unforeseeable disruptions (Pettit *et al.*, 2013; Scholten *et al.*, 2014) is of upcoming interest for academics and practitioners. Resilience enables a supply chain to be prepared for events, reduce the impact of a disruption and strengthens the ability to recover quickly from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function (Ponomarov and Holcomb, 2009). Although supply chain resilience has been clearly defined, the underlying elements of the concept differ within theory (Scholten *et al.*, 2014). However, taking a closer look at the body of literature on supply chain resilience, and comparing the underlying constructs and capabilities used, points toward some overlap. Table I depicts the similarities and differences in the conceptualization of supply chain resilience in research to date.

Supply chain resilience needs to be designed into a supply chain which requires trade-offs between redundancy (human, physical or organizational resources) and efficiency (Christopher and Peck, 2004). At the same time, however, creating and maintaining resilience is not a one-time event, but rather a process in itself (Pettit *et al.*, 2013; Scholten *et al.*, 2014): formative resilience elements are based on integrating and coordinating resources manifested in supply chain processes (Jüttner and Maklan, 2011). Therefore, different to some of the research in Table I, we consider redundant resources (and the need to balance it with efficiency) as a prerequisite to resilience, as they enable the necessary supply chain processes. In line with that, we will draw on the well-accepted (Johnson *et al.*, 2013) framework of Jüttner and Maklan (2011) who capture the adaptive capacity of supply chain resilience as flexibility, velocity, visibility and collaboration.

Flexibility facilitates coordination processes and enables organizations to deal with high levels of uncertainty (Manuj and Mentzer, 2008; Scholten *et al.*, 2014). It allows a supply chain to effectively adapt to (un)foreseen changes (Tummala *et al.*, 2006). Strong supply chain relationships, contracts that allow for modifications in delivery schedules, manufacturing facilities that can be used to produce multiple products, redundancy in terms of slack or unused resources and a multi-skilled workforce are factors that enable flexibility in the supply chain (Johnson *et al.*, 2013; Sheffi and Rice, 2005). Although flexibility enables an effective response to disruption, it needs to be balanced with the need for efficiency (Pettit *et al.*, 2010, 2013). Velocity places a strong emphasis on the efficiency of the supply chain's response and recovery (Jüttner and Maklan, 2011; Smith, 2004; Stevenson and

Table I Resilience constructs used in previous studies

Authors	Efficiency	Redundancy	Collaboration	Flexibility	Velocity	Visibility	Robustness
Christopher and Peck (2004)	✓	✓	✓	✓	✓	✓	
Sheffi and Rice (2005), Sheffi (2005)	✓	✓	✓	✓	✓	✓	
Ponomarov and Holcomb (2009)	✓	✓	✓	✓	✓	✓	
Pettit *et al.* (2010, 2013)	✓	✓	✓	✓	✓	✓	
Blackhurst *et al.* (2011)	✓	✓	✓	✓	✓	✓	
Jüttner and Maklan (2011)	✓	✓	✓		✓	✓	
Wieland and Wallenburg (2012, 2013)			✓	✓	✓	✓	
			✓	✓	✓	✓	✓

Source: Adapted from Scholten *et al.* (2014)

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Spring, 2007). Higher supply chain velocity in this regard leads to quicker response to market changes or events (Christopher and Peck, 2004) and helps to improve the speed of recovery from disruptions (Jüttner and Maklan, 2011; Wieland and Wallenburg, 2013). Furthermore, supply chain visibility, the ability to see from one end of the pipeline to the other (Christopher and Peck, 2004), is important for supply chain resilience. Visibility is determined by the extent to which supply chain actors have access to, or timely, share information that is of key importance to operations (Jüttner and Maklan, 2011). As it can be considered a prerequisite for responding to changes (Wieland and Wallenburg, 2013) and also strongly influences disruption recovery (Blackhurst *et al.*, 2005), visibility has been labeled as an antecedent of supply chain resilience (Brandon-Jones *et al.*, 2014). Velocity, visibility and flexibility are further defined in Table II.

As supply chain resilience is a network-wide concept, it is not enough for one organization to strive for flexibility, velocity and visibility; the formative elements of supply chain resilience have to be adopted by all members of a supply chain to align forces in the case of a risk event (Jüttner and Maklan, 2011). Hence, supply chain collaboration is important. At the same time, it has been shown that organizations engaged in collaborative relationships achieve improved visibility, higher service levels, increased flexibility, greater end-customer satisfaction and reduced cycle times (Daugherty *et al.*, 2006). Hence, the underlying resilience capabilities flexibility, visibility and velocity influence and are influenced by some form of collaboration in the supply chain. However, although it is clear that collaboration is one of the formative elements of supply chain resilience, it remains unclear how it exactly influences resilience and more specifically the three other formative elements. In line with the aim of our paper, the following section will further elaborate on collaboration.

Collaboration

Supply chain collaboration enables the development of synergies among partners, facilitates joint planning and encourages real-time information exchange (Whipple and Russell, 2007) required to prepare for, respond to and recover from supply chain disruptions while reducing their impact. Many authors cite mutuality of benefit, rewards and risk-sharing together with the exchange of information as the foundation of collaboration (Barratt, 2004). For instance, Daugherty *et al.* (2006) state that collaboration is about information-sharing, jointly developing strategic plans and synchronizing operations; Nyaga *et al.* (2010) refer to information-sharing, joint relationship effort and dedicated investments, whereas the architecture of Simatupang and Sridharan (2008) of supply chain collaborations contains the collaborative activities information-sharing, decision synchronization and incentive alignment. Here, we follow the recent research of Cao *et al.* (2010) who offer the most elaborated conceptualization of supply chain collaboration to date. The authors define collaboration via the collaborative activities of information-sharing, goal congruence, joint decision-making, resources-sharing, incentive alignment, collaborative communication and joint knowledge creation

Table II The adaptive capacity of supply chain resilience

Formative element	Construct	Definition
Flexibility	Flexibility	The ease with which a supply chain can change its range number (i.e. the number of possible "options") and range heterogeneity (i.e. the degree of difference between the "options") in order to cope with a range of market changes/events while performing comparably well. (Jüttner and Maklan, 2011)
Velocity	Velocity	The speed with which a supply chain can react to market changes/events. (Jüttner and Maklan, 2011)
Visibility	Visibility	The extent to which supply chain actors have access to, or timely share information about supply chain operations, other actors and management which they consider as being key or useful to their operations. (Jüttner and Maklan, 2011)
Collaboration (adapted from Cao *et al.*, 2010)	Information-sharing	The extent to which a firm shares a variety of relevant, accurate, complete and confidential ideas, plans, and procedures with its supply chain partners in a timely manner
	Goal congruence	The extent to which supply chain partners perceive their own objectives are satisfied by accomplishing the supply chain objectives
	Decision synchronization	The process where supply chain partners orchestrate decisions in supply chain planning, operations & solution seeking such as inventory management, demand forecasting or product assortment that optimize supply chain benefits
	Incentive alignment	The process of co-developing systems to evaluate and publicise each other's performance, sharing costs, risks, and benefits among supply chain partners
	Resource-sharing	The process of leveraging capabilities, resources and assets as well as investing in capabilities, resources and assets with supply chain partners
	Collaborative communication	The contact and message transmission process among supply chain partners in terms of frequency, direction, mode, and influence strategy
	Joint knowledge creation	The extent to which supply chain partners develop a better understanding of and response to the market and competitive environment by learning and working together

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among independent supply chain partners. These concepts are further defined and operationalized in Table II.

Although supply chain collaboration brings about many benefits such as higher visibility, flexibility and reduced lead times, it might not always be possible (e.g. a local manufacturer vs Microsoft) or wanted (see Kraljic (1983) Matrix) to establish long-term collaborative relationships covering all collaborative elements in Table II with all supply chain partners. Conducting collaborative activities with suppliers should be driven by a clear business need and a convergence of interests (Bowersox, 1990). Reducing the impact of any disruptions in the supply chain presents a clear business need and convergence of interests (goal congruence). Nevertheless, how to collaborate and what collaborative activities are important remains unclear. While some literature suggests that single sourcing increases vulnerability and possible impact of a disruption (Christopher and Peck, 2004; Jüttner, 2005; Pettit *et al.*, 2010), others state that increased collaboration and information-sharing – which is present to a higher degree in single sourcing relations (Skjoett-Larsen *et al.*, 2007) – are mitigators, as they help to make risk response processes faster (Ergun *et al.*, 2010). Furthermore, it is known that decision synchronization and incentive alignment are essential for effective system-level disruption responses (Jüttner and Maklan, 2011) and communication for supply chain resilience (Wieland and Wallenburg, 2013). Hence, previous studies show that collaboration is important to improve responsiveness and mitigate effects of a disruption, yet we do not know how the underlying activities of supply chain collaboration (here as per Cao *et al.*, 2010) influence supply chain resilience (here as per Jüttner and Maklan, 2011). We will explore the detailed relationships and effects between the two concepts via an in-depth multiple case study.

Methodology

Research design and case selection

To empirically investigate the underlying collaborative activities and their link to supply chain resilience, we adopted a multiple case study design (Eisenhardt and Graebner, 2007; Eisenhardt, 1989). Case study research is particularly suited to explore a real-life (complex, unique, exploratory) phenomenon in-depth (Yin, 2009) – here, supply chain resilience. The unit of analysis in this study is buyer–supplier relationships. We studied eight relationships in the network context of two buyers (focal companies) and eight of their suppliers. Such relationships are embedded in the network and are affected by the networks effects, which means that the boundaries between the context and the phenomenon cannot be clearly defined (Kähkönen, 2014). For such circumstances, the suitability of case study research has been highlighted (Yin, 2009).

Both companies (named as X and Y) are food processing companies from the fast-moving consumer goods (FMCG) sector with their head quarter (HQ) in The Netherlands. The case organizations are of particular interest for investigating supply chain resilience: X is certified in business continuity management [i.e. has developed plans to be resilient (Rice and Caniato, 2003)] and actively seeks to increase its supply chains' resilience; Y is a multi-national company with a very complex supply network exposed to many risks and has recently completed the first phase (risk mapping) of a project that aims to increase supply chain resilience upstream. Hence, both organizations actively and intensely manage their supply chain upstream to avoid any type of disruption affecting their customers and possibly leading to a decline in market share. Furthermore, the FMCG characteristics of high volumes moving quickly through the supply chain, combined with short shelf-life of the finished food products and most raw materials, make the two companies highly vulnerable to disruptions. Therefore, creating a resilient supply chain is of utmost importance: for example, during 2013, supply disruptions at X have caused damage for over €1,000,000 in terms of lost customer revenues, destroyed raw materials and additional resources required to process lower-quality raw materials.

In selecting specific buyer–supplier relationships, we purposefully sought out suppliers from different sourcing categories that are of great importance (financial spend and/or supply of key product) to the focal companies in terms of getting products to the market, i.e. if a disruption occurs, it has a severe effect. Therefore, we expected that in these cases, a lot of effort is put into collaborating and creating supply chain resilience, providing a solid base to explore how collaboration influences resilience. Additionally, after the initial analysis of cases in relation to Y when selecting cases for X, we became more specific, seeking further theoretical variation based on specific collaborative activities identified to influence supply chain resilience (information-sharing/collaborative communication and decision synchronization) as well as dependence. This allowed us to select cases that range on a continuum of a high to low degree of collaborative activities (Table III).

Data collection

The main source of data in this study was 16 semi-structured interviews collected between January 2013 and May 2014. For each case, we organized individual face-to-face interviews with the supplier and the focal companies (an overview is presented in Table III). As we were particularly interested in studying specific events during preparedness, response and recovery interviewees were chosen based on their knowledge on interactions with the other party during historical supply chain disruptions. Grounded in the initial literature review, an interview protocol was developed, allowing for comparability of answers and improving the reliability of the study (Yin, 2009). Accordingly, the interviews followed a standard core organized under broadly defined topics in relation to specific past disruptions, with open-ended questions and probes to encourage detailed responses. All interviews began with general questions about the background and position of the interviewee and the history of the relationship. Afterward, we asked participants to recall specific past supply chain disruptions that interrupted the flow of goods between X/Y and their suppliers. We were particularly interested in how the disruption was handled on either side and jointly. All, but one interview, were recorded and transcribed, following the 24-hour rule (Eisenhardt, 1989). In one case where we were not able to record the interview, detailed notes were taken by two researchers during the interview supplemented with further information and impression straight after the

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Table III Case and interview details

Case	Category	Company	Position of the interviewee	Length of the interview (minutes)	Collaborative activities
Case YA	Packaging	A	Account Manager	45	
		Y	Category Manager	100	
Case YB	Raw material	B	Account Manager	120	
		Y	Sales Manager	75	
Case YC	Raw material	C	Manager production planning and customer service	90	
		Y	Category Manager	90	
Case YD	Logistics	D	Operations Manager	60	
		Y	Category Manager Logistics Analyst	75	
Case XE	Raw material	E	Account Manager	70	Only share information if needed
		X	Buyer	60	No decision synchronization Mutually not dependent on each other
Case XF	Packaging	F	Supply Chain Analyst Supply Chain Planner	50	Share information on forecasts (weekly) and prices (twice a year)
		X	Buyer	65	Decision synchronization regarding product development X more dependent on F than F on X
Case XG	Raw material	G	Account Manager	75	Regularly and proactively share relevant, timely, accurate and complete information
		X	Buyer	50	High amount of decision synchronization regarding product assortment and development, managing inventory and partly on working out solutions Mutual dependency as both dependent on same customer
Case XH	Raw material	H	Commercial Director	50	Frequently and proactively share relevant, timely, accurate and complete information
		X	Buyer	50	Decision synchronization is high on managing inventory, working out solutions together and partly on product development. High mutual dependence

conversation. We validated the transcribed interviews with informants by asking for feedback, clarification of any points and final approval (Yin, 2009).

To achieve internal triangulation (Voss *et al.*, 2002), additional information was gathered by attending meetings that involved the buyer and supplier, reviewing company documents (e.g. spend analysis, audit reports of suppliers, documented recent correspondence, enterprise resource planning [ERP] data, Web sites and supplier evaluations), informal conversations with people from the focal company and several site visits at both X, Y and six of the suppliers. These data were used to confirm statements from the interviews, gather additional background data and fill-in missing information.

Data analysis

The interviews were analyzed, following the three steps suggested by Miles and Huberman (1994): data reduction, data display and conclusion. We started by reducing the data to quotes, sentences and/or paragraphs that were truly relevant for answering the research question (first-order codes). Afterward, we examined the data from two different perspectives. First, we analyzed data in relation to collaboration. We coded all first-order codes into descriptive second-order categories such as "contractual obligation to supply", "hard to share forecasts" or "access to data bank supplier". This allowed us to get a first indication of the different kinds of collaborative activities that were taking place in the supply chain. Furthermore, it enabled us to deduce third-order themes in relation to the supply chain collaboration activities of Cao *et al.* (2010)[1] defined in Table II. In the second step, we examined the data in relation to supply chain resilience. Here, we deduced a link to the three supply chain resilience capabilities velocity, visibility and flexibility, defined in Table II, from first-order codes.

Next, we juxtaposed the two independent analyses in relation to supply chain collaboration and supply chain resilience to explore how specific collaborative activities influence the supply chain resilience capabilities (see Table IV for examples of coding). In the start of this analysis, we concentrated on individual cases to become intimately familiar with the distinct circumstances of each relationship (Eisenhardt, 1989). Accordingly, we summarized initial conclusions for each case based on the interviews and company documents in separate case narratives. We then proceeded to a cross-case analysis, initially across cases in relation to each focal company and then across all eight cases. In doing so, we were seeking to identify patterns that could explain how specific collaborative activities relate to the three resilience elements and, ultimately, reduction of the impact of a disruption. Of particular interest were also those data that we could not juxtapose, i.e. data that were coded for a resilience capability or a collaborative activity but not for both. This allowed us to identify additional factors such as mutual

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Table IV Excerpt of coding

Link to resilience capability	Data reduction (first-order codes)	Descriptive code (second-order categories)	Link to collaborative activity (third-order theme)
Visibility	"Suppliers have already seen that there is something wrong. What we want them to do is call us up front and mention this so we can then make decisions on whether they should ship out at all". (Buyer YB), "So the faster we know about any disruption, the more time we have to respond to that and possibly to set up a new batch, which we need". (Supplier XE)	Information on time	*Information-sharing and collaborative communication*
	"Providing good, complete and reliable information is crucial related to disruptions". (Supplier XG), "You need some information to make a decision. Indeed as much information as possible. But it is unlikely to be a full picture". (Supplier YB)	Quality of information	
	"We insisted on this daily contact between the supplier and the people in my team about what are the effects for deliveries, what is the outlook, which alternative backup plans do you have". (Buyer YC)	Detailed information	
	"What we want to have is also direct access to the traders of our suppliers because they are the one who are buying in the market and they have the understanding about the stock in supply and demand. When they see wired thing happening they can warn us". (Buyer YB)	Information beyond first tier	
	"When I pose the complaint to F, they react immediately and come to our factory to see the problems themselves". (Buyer XF), "I visit them this much because I want to see the developments in the products we will receive later on, what possible quality issues are and to anticipate possible disruptions in an early stage". (Buyer XH)	Site visit	
	"Our customer can see at an internet site 'where are my goods, where is the car, ETA?'. When the truck is falling down, a new ETA will be there so he can follow his goods". (Supplier YD)	Track and trace	
	"But I can show it for the primary packaging what we have prepared with the suppliers, what is going to happen if you are having a problem, if a site is down. How much time does it take when you can catch up top supply to Y". (Buyer YA)	Jointly created contingency plans	*Mutually created knowledge*
	"H has visited X a lot of times over the years, so they know exactly how we process their products. Because of that, they are able to estimate when their products are not suited to use at X and when they are. This helps us to anticipate any possible disruptions early on". (Supplier XH)	Years' experience	
	"I think it is important that we know from each other why we are doing certain things and why we can for example not change orders later on. So it is important to have insights in the process of X and that they know about our processes, so both of us know that early anticipation to disruptions is important and we can respond to disruptions faster in this way". (Supplier XE)	Insights into processes	
Velocity	"Suppliers have already seen that there is something wrong. What we want them to do is call us up front and mention this so we can then make decisions on whether they should ship out at all". (Buyer YB)	Information on time	*Information-sharing and collaborative communication*
	"Because I went to visit the production location of X immediately and actually could see what was happening over there, I was able to respond to this issue in a quick manner and better explain to people from E what was happening as well". (Supplier XE)	Site visit	
	"We did not think about the possibility that X might help out here in sending one of their trucks to pick up the product". (Supplier XE)	Send truck to help	*Joint relationship efforts*: resource-sharing

(***continued***)

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Table IV

Link to resilience capability	Data reduction (first-order codes)	Descriptive code (second-order categories)	Link to collaborative activity (third-order theme)
Velocity	"We send a bunch of quality people there, experienced guys with all kind of tests, just to see if the material was affected or not. That was done by us ourselves that was done by the supplier and then in the end there was nothing wrong with that stock of them, so they released the stock and we packed and no problem". (Buyer YA)	Joint quality checks	
	"Not just letting F solve the problem, but we would be very proactive in providing possible options to solve the problem or when possible even adapt our own processes or specifications if that is the only way to solve this". (Buyer XF)	Joint solution seeking	*Joint relationship efforts*: decision synchronization
	"I would evaluate this with E, especially when it is a big problem, because we might be able to learn from this for the future". (Buyer XE), "The funny thing is that the exact same accident happened again half a year later. In that case we did recognize the mistake immediately and informed X about this". (Supplier XF)	Learning	*Mutual knowledge creation*
Flexibility	"If we know that a certain product is not needed for a while through receiving the information about the breakdown at X, we can adapt our planning with that and make sure we do not create unnecessary stock". (Supplier XF)	Two-way knowledge flow	*Information-sharing and collaborative communication*
	"In cases like that, they call me that they need some product as soon as possible. Then I change my planning and do everything to make sure that we can deliver to X as soon as possible". (Supplier XH)	Change planning	
	"So if we know that we cannot deliver, we ask Y to ask their second supplier. If it is at such short notice that their second supplier doesn't agree, we ask Y to adjust their production planning. If not, we make sure that we either deliver half of it now and half of it later. We try to work together". (Supplier YB), "In that case we have to look for a solution together, to see what the possibilities are. In what way we are able to still process the product, for example with some additional-, or rework at H". (Buyer XH)	Joint solution seeking	*Joint relationship efforts*: decision synchronization
	"You were in need last time. We helped you. Maybe this time you can help us". (Supplier YC), "We would let the products be processed for example at competitors, even if we have to pay extreme high prices, as long as we can deliver to X". (Supplier XG)	Competitor	*Joint relationship efforts*: incentive alignment
	"We are now in discussion with Y about whether we need a contingency plan in place for all high runners and probably have a reserve knife or printing plate somewhere else in case of problems". (Supplier YA)	Dedicated investment	*No direct link* (via mutual dependency)
Indirect as it increases level of collaborative activities	"We depend on them, so we really have to push them". (Buyer YA), "Y was not affected, since we have to decide internally which customers will get this paper [that was still in stock] and other customers we informed whether they can use other material". (Supplier YA)	Mutual dependency	*Information-sharing and collaborative communication*
	"We as G do treat X in this way because we do not want to make mistakes, especially because X delivers to our customer as well and when they cannot deliver because of an issue with one of our products, I know that the common customer would blame us for this as well. So we and X both have the same goal, namely to make sure we can deliver to the common customer". (Supplier XG)		

dependency which directly influences collaborative activities but is only indirectly linked to supply chain resilience. Table IV depicts an excerpt of our in-depth analysis, demonstrating how we progressed from data reduction (first-order codes) over descriptive codes (second-order categories) to third-order themes grounded in and deduced from the literature.

Multiple measures were taken to safeguard the trustworthiness of the qualitative data and their analysis, as we followed a recursive iterative process to first, relate our data and findings to the existing theoretical frameworks and literature (Eisenhardt and Graebner, 2007) and second, rule out alternative interpretations (Yin, 2009). It needs to be highlighted that because of the in-depth qualitative rather than quantitative nature of data collected, required in line with the aim of our research, the emphasis in this study is on analytical generalization toward theoretical concepts rather than statistical generalization through, for example, correlation analysis to populations or universes (Jüttner and Maklan, 2011).

Findings

In analyzing our data, we were able to unravel specific details on how the collaborative activities of information-sharing and collaborative communication, joint relationship efforts (decision synchronization, resource-sharing and incentive alignment) and mutually created knowledge enable visibility, velocity and flexibility. Furthermore, mutual dependency was found to influence supply chain resilience as well. Following the mechanisms identified for each dimension will be outlined in detail.

Information-sharing and collaborative communication

Our findings highlight the importance of information-sharing and collaborative communication in improving supply chain resilience, as they not only increase visibility but also improve flexibility and velocity. To achieve visibility and ultimately supply chain resilience via information-sharing, organizations need to consider the type of information that is shared (orders, forecasts, shipping information, upcoming disruptions, market trends and maintenance schedules), frequency, direction as well as mode of information-sharing. In our interviews, face-to-face contact followed by communication via phone was mentioned to be the best ways to anticipate and/or quickly solve supply chain disruptions. Site visits help to generate insights and visibility in the processes of the other company, which, in turn, enable the recognition of possible disruptions early on as the following exemplary quote shows:

> The buyer of X visits us once a week, then we have a look at the products that we are about to deliver to X. In that way we can make sure that we can anticipate possible quality or quantity issues early on (Supplier XH).

Phone contact not only allows to quickly share detailed information in anticipation, but it is also of particular importance to give regular (hourly, daily) updates when trying to respond to a disruption:

> We first call up the customer and ask, how much can it be delayed before they are faced with problems. Because why would we need to make a lot of costs if the customers says "oh you can supply 12 hours later". So we try to smoothen this disruption in the supply chain by checking (Supplier YB).

Similarly, technology such as track and trace information that is provided to Y in Cases YB, YC and YD can create visibility and support the anticipation of possible disruptions.

Furthermore, we found that the right type of information available in time leads to more velocity, reducing the time needed to anticipate, respond to and recover from a disruption. This gives the "customer the opportunity to do something, reduce the production or delay the production, talk to other supplier, whatever. They have the opportunity to do something that's important". (Supplier YC). Our data highlight that such information should also be shared in the other direction: if the buyer has a disruption because of one component, the Supplier YC "would like to know, because then we put that in our systems and plan it. That we don't have deliveries". However, we also found that "I give myself 24 hours to find a solution, after that I will inform X about the disruption" (Supplier XG), as "it depends on what happened and how will your supply chain and processes be affected" (Supplier YA). Although some disruptions might not affect the overall supply chain directly (see example of Supplier YB above), the analysis of data points to the possibility of severe impacts on velocity and ultimately disruption recovery if information about possible problems is not shared early on, which led to a lack of information regarding quality issues in raw materials:

> They [Supplier's supplier XG] did not inform us or G about this and did not specify this with their product either. So they actually did not provide us with the time to anticipate on the fact that something like this might happen (Buyer XG).

As a consequence, production had to stop for the related final products and with that deliveries to the customer of X on two consecutive days. For Company X, this had a high impact on profit, and goals for customer delivery performance were not met. Additionally, we found that having a lack of information or receiving the right information too late can also affect flexibility needed to respond to a(n upcoming) disruption. The two underlying reasons identified in our data were fixed production schedules and already ordered/processed raw material stock. Hence, receiving the right information on time allows for velocity and flexibility, so that changes to processes can be made early enough. This might ultimately enable continuity of production and delivery of products to the end-customer.

Overall, our findings show that quantity, direction and timing of detailed, reliable and complete information not only related to disruptions but also, in general, lead to more visibility and velocity and, in that way, improves supply chain resilience. At the same time, we found that low levels or information-sharing and collaborative communication reduce flexibility and, therefore, resilience.

Joint relationship effort

In addition to information-sharing, the collaborative activities of decision synchronization, resource-sharing and incentive alignment, which we summarized under the heading of joint relationship efforts, also contribute to supply chain resilience. Particularly, decision synchronization via joint problem-solving and resource-sharing emerged from our data as improving velocity and flexibility in responding to (upcoming) disruptions. In our cases, this could take various shapes such

as sharing transportation (Case XE) or personnel (Case YA), helping the other company to find a solution via site visits (Case YB) or adapting processes in both companies to respond quickly to a disruption (Case XH).

Most interestingly, competitors also play an important role in the effort to reduce the impact of a disruption: "If they need the goods and we don't have a truck here, outside there's a competitor they always have a truck we can use" (Supplier YD). Similarly, in Case XG, where the Supplier "would let the products be processed for example at competitors, even if we have to pay extreme high prices, as long as we can deliver to X", or in Case YB, where the Supplier would actively encourage Y to use their second supplier "if we know that we cannot deliver". On the one hand, this reflects on a low degree of incentive alignment between the focal companies and their suppliers as such actions would often be taken to avoid additional fees based on contractual agreements ("Our reaction is from legal perspective. We have the contract so you have to deliver. We push our suppliers from contract perspective" [Buyer YB]); however, on the other hand, it can be considered incentive alignment between competitors as "you were in need last time. We helped you. Maybe this time you can help us" (Supplier YC).

Hence, overall, we found strong indications that joint relationship efforts lead to improved velocity and flexibility, enabling an efficient and effective response to disruptions. Furthermore, competitors can contribute to increased supply chain resilience by creating flexibility and velocity in responding to a disruption.

Mutual dependency

Our data indicate that mutual dependency between two parties or mutual dependence on a third party leads to more willingness to share information, joint solution seeking (joint relationship efforts), hence, learning, as well as dedicated investments, therefore, indirectly increasing resilience. As was declared by the buyer of Case XH: "I would communicate this directly to H, because they are highly dependent on X and in the end this will cost X a lot of money" and "they are doing this [Informing me right away], because they know how important this product is for X". The effect of dependency is further emphasized by the Supplier XG, stating: "Overall, this communication is always very fast and collaborative, because we together do everything to make sure that we can deliver to our common customer quickly". Hence, we also observed that the mutual dependency on a third party has a similar effect. Both X and G depend on the same customer, which requires them to collaborate in terms of information-sharing and joint activities increasing visibility, velocity and flexibility.

In our analysis, we also found that mutual dependency is created through dedicated investments specifically made to increase the performance of this particular supply chain. Although redundant capacity and stock is often used to mitigate possible disruptions, our data indicate that investments in machines (or processes) may lead to more flexibility, which, in turn, increases supply chain resilience. In Case XH, the supplier strives for 100 per cent reliability and, therefore, "did some specific investments in our machines, to make sure we can deliver at any time". Similarly, in Case A, the supplier describes that:

> [. . .] we are now in discussion with Y about whether we need a contingency plan in place for all high runners and probably have a reserve knife or printing plate somewhere else in case of problems which creates flexibility in terms of production.

However, we also found that trade-offs have to be made between increased flexibility because of mutual dependency based on dedicated investments and the risk of less flexibility as a result of investments that automatically tie two partners together. Consequently, it might be, for example, more difficult to engage a second supplier in the sourcing process if an organization is tight to a single supplier via specific processes and investments.

Overall, mutual dependency is indicated to improve the degree of collaboration (information-sharing, collaborative communication, decision synchronization, incentive alignment, resource-sharing and joint knowledge creation) and, in turn, indirectly increases supply chain resilience.

Joint knowledge creation

Our findings indicate that mutually created knowledge also leads to more supply chain resilience. We particularly identified joint learning and the length of time organizations have been working together to influence visibility and velocity. The review of disruptions jointly to learn from them seems to be a common practice, as we observed it in all cases. "In case they [Y] have been affected yes there [. . .] definitely a meeting afterwards 'how did it go, what can we do better'" (Supplier YA) and "reviewing again where are our vulnerabilities and discuss with suppliers what can we do the next time" (Buyer YA). The importance of shared learning across the organizations to increase visibility is also emphasized "to anticipate disruptions that might happen in the future" (Buyer XF) and "to prevent things like this and to be able to respond even better with future disruptions". (Buyer XH). Additionally, our findings indicate that joint learning through the analysis of past disruptions enables velocity, as illustrated by the Supplier XF: "The funny thing is that the exact same accident happened again half a year later. In that case we did recognize the mistake immediately and informed X about this".

Furthermore, we found that mutually created knowledge not directly related to disruptions (i.e. day-to-day practices) increases supply chain resilience: companies get insights into each other's processes which improves visibility and velocity. As explained by the Supplier XG:

> I am involved in a lot of activities like the joint product development [. . .] this really helps me to get insights in what is needed at X and to respond to complaints or disruptions effective and quick.

This also helps to deal with disruptions downstream caused by, for example, order variability. Supplier XH already anticipates on this because they "know how the processes of X are and how the order patterns usually are". Hence, mutually created knowledge can help to avoid disruptions in both directions of the supply chain. Most interestingly, jointly created knowledge over the years that organizations have been working together seems to offset a low level of information-sharing, collaborative communication and joint relationship effort: we found Case XF with low collaborative activities and no mutual dependence to be of comparable resilience (similar visibility and flexibility) as Case XG which displays high collaborative activities and mutual dependence. F and X have

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been working together for over 25 years; hence, "they [F] know from experience what X wants and help us to develop new ideas" (Buyer XF). This creates visibility in the chain, as companies have knowledge about each other's processes, making it easy to "solve disruptions quickly and also to see some disruptions coming in an early stage" (Supplier XF), indicating also improved velocity. Therefore, joint knowledge creation through learning, particularly over a lengthy relationship, increases supply chain resilience via visibility and velocity.

Discussion

As the frequency and impact of supply chain disruptions remain stubbornly high (Brandon-Jones *et al.*, 2014), resilient supply chains that are able to absorb such shocks (Sheffi and Rice, 2005) via visibility, velocity, flexibility and collaboration (Jüttner and Maklan, 2011) are of great importance. Our paper contributes valuable empirical insights into the concept of supply chain resilience in relation to collaboration. Extending Brandon-Jones *et al.*'s (2014) findings that visibility is an antecedent of supply chain resilience, our research shows that collaborative activities antecede visibility and, therefore, resilience. Organizations engaged in collaboration achieve improved visibility, increased flexibility and reduced cycle times (Daugherty *et al.*, 2006). Consequently, collaboration does not directly, but indirectly lead to a more resilient supply chain, as it is not a construct of resilience, but an antecedent of visibility, velocity and flexibility.

Collaboration as an antecedent to supply chain resilience

Supply chain collaboration relates to different organizations engaging in collaborative activities together: information-sharing, goal congruence, decision synchronization, incentive alignment, resource-sharing, collaborative communication and joint knowledge creation (Cao *et al.*, 2010). Visibility is an outcome of investments in information-sharing (Barratt and Oke, 2007; Brandon-Jones *et al.*, 2014; Daugherty *et al.*, 2006), collaborative communication (Brandon-Jones *et al.*, 2014; Wieland and Wallenburg, 2013) and mutually created knowledge. Our findings indicate that information-sharing and collaborative communication help to improve supply chain visibility by providing transparency needed to detect and respond to disruptions upstream and downstream. At the same time, knowledge of processes and procedures is created jointly, which we found further increased visibility while ensuring confidence into the supply chain, so that over-reactions, unnecessary interventions and ineffective decisions in a risk event situation can be prevented (Christopher and Lee, 2004).

While research by Wieland and Wallenburg (2013) found that increased cooperation, the process by which individual and organizations conduct activities together for mutual gain or benefit, hence, joint relationship effort, is associated with increased levels of visibility and velocity, our findings only show a link between joint relationship efforts and velocity. This can be explained by the fact that their research incorporates collaborative communication and information-sharing within cooperation, as "cooperation goes beyond the flow of information inherent to communicative relationships" (Wieland and Wallenburg, 2013, p. 302). In our analysis, however, we treated information-sharing and collaborative communication separately from joint relationship efforts. This enabled us to derive new fine grained insights. We particularly found that decision synchronization via joined solution-seeking and resource-sharing increases velocity in responding to (upcoming) disruptions. Additionally, we established that velocity is supported by the early sharing of good quality, complete and reliable information, as knowledge of processes within the supply chain enables anticipation, readiness and quick response to disruptions. At the same time, however, organizations typically delay the release of information about supply chain disruptions (Hendricks and Singhal, 2005), which is also reflected in our findings. As Case XG showed, this can have severe and long-term implications, as an efficient disruption response enabled by velocity was not possible.

Decision synchronization is essential for effective (flexibility rather than velocity) system-level disruption responses (Jüttner and Maklan, 2011) via adaption of processes. Our findings confirm this and show that joint relationship efforts increase flexibility. At the same time, in line with Chan *et al.* (2009), we found that having a lack of information, or receiving the right information too late (information-sharing), reduces flexibility that is needed to respond to a(n upcoming) disruption. The main underlying reason we identified is that when information is received late, production schedules are more fixed and raw material stocks have been ordered/processed, which makes it more difficult to stop the processes that are already moving, leading to a higher impact of disruptions.

Therefore, in line with our findings, all three resilience elements are outcomes of collaborative activities. Therefore, we propose that:

P1. Supply chain collaboration is an antecedent of visibility, velocity and flexibility, hence, supply chain resilience:
1. Information-sharing, collaborative communication and jointly created knowledge increase visibility and, hence, supply chain resilience.
2. Information-sharing, collaborative communication, joint relationship effort and jointly created knowledge increase velocity and, hence, supply chain resilience.
3. Joint relationship effort increases flexibility and, hence, supply chain resilience; a lack of information-sharing and collaborative communication reduces flexibility and, hence, supply chain resilience.

Our findings indicate only positive relationships between collaborative activities and supply chain resilience: the more companies engage in information-sharing, collaborative communication, joint relationship efforts and mutual knowledge creation, the higher the levels of visibility, velocity and flexibility, which ultimately leads to a more resilient supply chain. This is in line with suggestions from Faisal *et al.* (2006) who found, via interpretive structural modeling, that information-sharing, based on collaborative relationships, alignment of incentives and risk-sharing, helps a supply chain to respond in real time to disruptions, enabling flexibility and agility (visibility and velocity, as per Wieland and Wallenburg, 2012, 2013). We, therefore, propose that:

P2a. The higher the levels of collaborative activities in a supply chain, the higher the level of resilience in the supply chain.

At the same time, close collaboration and resulting high levels of collaborative activities are not always possible, wanted or needed. As a matter of fact, supply chain collaboration is positioned on the far right side on a continuum of potential supply chain relationships ranging from open market negotiations to collaboration (Spekman *et al.*, 1998). Ultimately, the level of collaboration is determined by characteristics of the market (demand and supply uncertainty), the product (criticality and customization level) as well as the partner (superior capabilities and dependence) (de Leeuw and Fransoo, 2009). In line with *P2a*, this would imply that transactional-based relationships, employing low levels of collaborative activities, always have supply chains with little or no resilience to disruptions. Surprisingly, however, we found that supply chains engaging in low levels of collaborative activities can be fairly resilient. This can be explained with the amount of mutually created knowledge: the longer companies have been working together, the more jointly created knowledge there is when a disruption occurs independent of the level of collaborative activities. Little information-sharing creates little visibility, however, over the years, builds up knowledge on processes and procedures – visibility (*P1a*) – that allows anticipation of a disruption early on and/or response to and recovery from a disruption quickly – velocity (*P1b*). Hence, the level of collaborative activities increases because of accumulation of jointly created knowledge over the years and, in line with *P2a*, the resilience of the supply chain. Similar to other works of literature that emphasize advantages of long-term relationships (Chen *et al.*, 2004; Singh and Power, 2009), we found that these are beneficial for supply chain resilience. Therefore, we pose that:

P2b. A high amount of mutually created knowledge can somewhat offset low levels of collaborative activities in the creation of a resilient supply chain.

The role of the supply network in creating resilience

To answer the research question of how underlying collaborative activities between supply chain members can lead to a resilient supply chain, we collected data from eight cases of buyer–supplier relationships. However, our findings clearly go beyond the dyadic level, showing that supply chain resilience is influenced by collaboration on a network level.

We found that mutual dependence between two organizations within a chain or on the same third party (e.g. a customer) indirectly increases supply chain resilience. Organizations who depend on one another make their success interdependent, share information freely, work together when trying to solve common problems or when designing new products and jointly plan for the future (Soosay *et al.*, 2008; Spekman *et al.*, 1998). Furthermore, interdependent organizations are more likely to engage in dedicated investments, which, in turn, increase mutual dependency (Nyaga *et al.*, 2010). This circular effect leads to path dependencies, which can decrease options of flexibility needed for resilience, for example, only one supplier being able to deliver a customized item. Therefore, our findings indicate that:

P3a. Mutual dependency between two organizations in a supply chain or mutual dependence on a third party indirectly increases supply chain resilience, as it leads to more willingness to share information, increased joint relationship effort and mutually created knowledge.

P3b. Mutual dependency between two organizations in a supply chain or mutual dependence on a third party indirectly leads to more willingness for specific investments. Dedicated investment leads to path dependencies, possibly decreasing flexibility and, in turn, supply chain resilience.

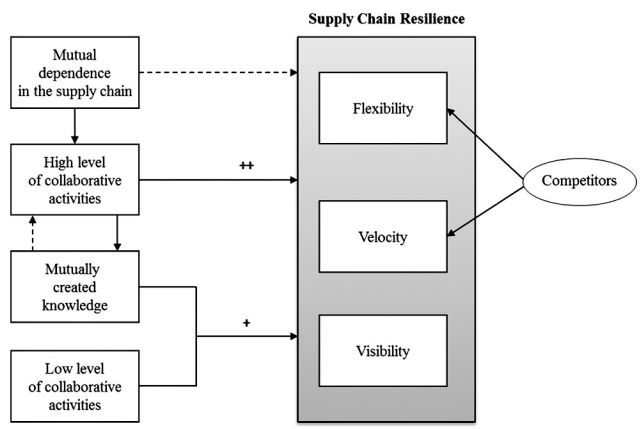
Furthermore, we found that the collaborative activity of incentive alignment within the supply network can increase supply chain resilience. "One hand washes the other" motivates competitors to help each other out in times of crises. Our analysis indicates that competitors' resources can help to create flexibility, i.e. additional supply to customer in case of disruption. At the same time, this means that the disruptions can be taken care of in a speedy way; hence, competitors also enable velocity. This finding lets us propose that:

P4. Supply chain resilience can be enhanced through collaboration with competitors.

Conclusion

The findings of this research contribute to the ongoing investigations on supply chain resilience by shedding light on the role of collaboration, as outlined in Figure 1. Although collaboration has been recognized as a formative element of supply chain resilience throughout the literature, our findings identify it to be an antecedent of the constructs of resilience. We were able to unravel specific underlying mechanisms of collaborative activities that lead to a resilient supply chain, which we explain in a series of propositions. As our study is one of the first to analyze supply chain resilience beyond a single company perspective, we are able to add valuable new insights on a supply chain, if not network level. This enabled

Figure 1 The influence of collaboration on supply chain resilience



us to determine that not only mutual dependencies but also competitors determine the level of resilience in a supply chain.

Managerial implications

Next to theoretical implications, this study also provides valuable managerial contributions. Although the positive effects of supply chain collaboration are known in theory and practice, we provide new insights demonstrating that collaboration is essential for building resilience and reducing the impact of possible inevitable disruptions. Hence, the findings of this research offer managers' guidance on how to use collaborative activities, so that visibility, velocity and flexibility can be improved. We determine, for example, that sharing information as soon as possible is of paramount importance to enable a quick response to (upcoming) disruptions. At the same time, in practice, we found counter-instances where managers waited to share information. Our examples show that this increases the impact of disruptions. Furthermore, we demonstrate that engaging with competitors, which might be counterintuitive for some managers, can increase resilience by enabling flexibility. In our cases, competitors were used as additional redundancies that do not need to be balanced with concerns about efficiency, but have to be incorporated into supply chain processes to allow incentive alignment between organizations in parallel supply chains.

We also found that the longer companies have been working together, the more resilient they become because of increased visibility and velocity. This theoretical insight is particularly relevant for managers, as it offers important guidance on questions in relation to sourcing: another supplier might offer better value; however, even when engaging in the same level of collaborative activities with the new supplier, resilience will be reduced. This might ultimately decrease the initial value promised by the new supplier.

Limitations and research implications

Even though we did our best to provide a valid and reliable study, there might be some limitations related to this research. To be able to explore underlying supply chain processes that contribute to resilience via flexibility, velocity, visibility and collaboration, we considered redundant (human, physical or organizational) network resources and their trade-offs with efficiency as a given. Therefore, we suggest for future research to explore redundant resources that are required for supply chain resilience, as they enable the supply chain processes we explored in our study. Furthermore, we would propose to investigate the balance of such redundancies with efficiency to find out how much efficiency a resilient supply chain can take.

In our research, we carefully selected cases from different sourcing categories that are of great importance (financial spend and/or supply of key product) to the focal companies. Yet, we did not study underlying risks, i.e. whether there are alternative suppliers available or what the market conditions are or power imbalance. We would, therefore, suggest for future research to consider the Kraljic's (1983) matrix when selecting cases, so that the underlying level of risk can be accounted for. Exploring the influence of power on mutual dependence, which we found to increase supply chain resilience, or in relation to legal agreements that we found to effect incentive alignment, is a second important issue that has to be studied in future research. This might give additional insights into why and how the level of resilience between supply chains differs. Finally, we recommend for future research to empirically test our propositions with quantitative data, so that generalizability and validity of our findings are increased.

Note

1 We did not code any data for goal congruence, as we assumed supply chain resilience or reduction of the impact of (possible) disruption to reflect a convergence of interests.

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