

Mitigation proposal for the enhancement of enterprise resilience against supply disruptions

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Abstract: The current context is characterised by growing uncertainty, insecurities and risks. To overcome this situation, enterprises need to be resilient enough to guarantee its business continuity. This research is focused on the preparedness capacity, one of the three constituent capacities of enterprise resilience. To be prepared for the unexpected, it is necessary to identify, the most critical disruptive events companies face from a supply side and propose mitigation actions to provide companies with a set of alternatives to support the enhancement of the preparedness capacity of enterprise resilience. This research offers valuable information about both aspects; an analysis of the most worrisome supply disruptive events and a proposal of preventive actions as mitigation policies.

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1. INTRODUCTION

The current context is characterised by growing uncertainty, insecurities and risks. To manage risks in an efficient way and build resilience to their impacts, enhanced efforts are needed to understand the disruptive events that threaten the daily and normal level of enterprise operation. The assessment and improvement of a proactive attitude to forecast and advance the negative effects of an imminent adverse situation is essential. Therefore, it is necessary to build resilient enterprises that not only give a capable response once that the threat has occurred but try to protect before its occurrence.

The concept of resilience was first defined in the ecological field by Holling (1973) who defines resilience term as a system that persists in a state of equilibrium and how dynamic systems behave when they are stressed and move from this stability. Ponis and Koronis, (2012) analyse the concept of resilience in different areas of study in order to develop the concept and identify its components. Sanchis and Poler (2013) define the main research areas of the Enterprise Resilience (RE) properties to provide the basis for further research. Pavlov et al., (2018) study the ripple effect and structure reconfiguration to assess ER in supply chains. However, what ER is? From a business viewpoint, in the literature we find numerous definitions of ER. Gallopín (2006) describes ER as an enterprise adaptative capacity and its ability to cope with, adapt and recover after a disruption. Pereira et al., (2014) defines ER as the capability to respond quickly to unexpected events so as to restore operations to the previous performance level or even to a new and better one. Based on this definition, the ER can be considered as a reactive ability to give response to adverse situations that have already occurred. However, there are definitions in the literature that have a broader scope as they are not only focused on the reactive response but also on the proactive

behaviour to make enterprises be prepared in advance to face the impact of threats. In light of this, we also find some definitions of ER in literature that has into account this proactive perspective. This is the case of Hollnagel (2006) who defines ER as the capacity of a system to forecast, recognise, anticipate and defend against risks before adverse consequences occur; and Hohenstein et al., (2015), among others, who define resilience as the ability to be prepared for unexpected risk events, responding and recovering quickly to potential disruptions to return to its original situation or grow by moving to a new, more desirable state in order to increase customer service, market share and financial performance.

Therefore, based on the previous review, three different perspectives are identified in the ER definitions. The first perspective covers the proactive view, in which enterprises should be prepared to foresee and prevent the negative effects of disruptions. The second perspective has a reactive nature, and it covers the recovery ability. With this ability enterprises will try to restore operations after disruptions occurrence. The third and last perspective has an on-going nature that is the adaptative capacity that can be understood as the ability to adjust and modify enterprises behaviours to fit the changing environment.

This research is focused on the first perspective of ER, the preparedness capacity. This constituent capacity of ER needs to identify what are the critical threats to monitor the frequency and/or severity of these risks and to propose actions to make enterprise more prepared to face these situations. For this reason, the main objective of this paper to identify, firstly, the most crucial disruptive events companies face from the supply side and, secondly, to propose mitigation actions to provide companies with a set of alternatives to support the enhancement of the preparedness capacity of ER.

The paper is organised as follows. Section 2 highlights the difference between mitigation and contingency policies and offers a literature review focused on the first ones, particularly applied to the supply side. Section 3 describes the mitigation proposal. Finally, section 4 highlights the main conclusions and further research

2. MITIGATION POLICIES TO ENHANCE ER CAPACITY

To improve ER, the actions to be implemented will be defined according to the moment in which they are adopted to diminish the effects of disruptive events. Tomlin (2006) describes two general approaches to deal with disruptive events: mitigation and contingency policies. Sanchis and Poler (2012) also affirm that the actions to enhance the ER capacity must cover two different perspectives, on one hand, proactive actions that advance to the adverse situations, and on the other hand, reactive actions, that are applied to facilitate the recovery process once the disruptive event has occurred. Both types of actions must be planned before disruptive event occurrence, however, mitigation policies are implemented before the event happening, while contingency policies are, in general, implemented after the event manifestation. In this research, mitigation policies are referred to preventive actions to improve the preparedness capacity of ER.

The companies that wishes to improve their preparedness capacity to face adverse situations, implement certain practices before the disruptive event occurrence, and therefore they incur a cost, regardless of whether the event occurs or not. With contingency policies, the company only implements actions in case of the evident event occurrence. Therefore, mitigation policies are essentially proactive in nature, while contingency policies are reactive (Craighead et al., 2007). A proactive policy emphasizes preventive plans to define what can be done, in order to avoid specific disruptive events or prevent their appearance as much as possible. For those inevitable disruptive events, the effort must be focused on controlling its negative consequences.

The selection of which policy to adopt generally depends on the potential negative consequences of the disruptive event or the probability of occurrence. Sometimes, mitigation policies are in conflict with the objectives and processes of a company, e.g. the balance between efficiency and redundant inventory. Maintaining redundant inventory will provide a safety inventory to guarantee the continuity of operations for a time if a disruptive event occurs. However, it will also mean an increase in costs and will lead to lower efficiency (Barroso, Machado and Machado, 2011). Therefore, a trade-off between the company's global objectives and the ER objectives must be found.

Barroso, Machado and Machado, (2011) offer a review analysis of the mitigation policies (Table 1) when disruptive events have as origin supply aspects. Chopra and Sodhi (2004) point out the following general preventive actions as effective for the enhancement of ER: capacity increase, safety stock, supplier base redundancy, flexibility, aggregate demand, business capabilities enhancement s and customers

diversification, so that there is no a high dependence on a single key customer. Each of these preventive actions is addressed in a general way to improve widely the preparedness capacity, however specific preventive actions addressed to particular and real disruptive events are required. Moreover, it is worth mentioning that not all preventive actions are adequate for all disruptive events and for this reason, preventive actions should be adapted according to the specificity and characteristics of the potential disruptive events.

Table 1. Overview of the supply side mitigation policies reviewed by Barroso, Machado and Machado (2011).

Mitigation policy	Authors
Safety stock	Baker (2007); Zsidisin, Panellu and Upton (2000)
Multi-sourcing	Baker (2007); Zsidisin, Panellu and Upton (2000); Svensson (2003)
Collaboration with supplier	Zsidisin, Panellu and Upton (2000); Christopher and Peck (2004)
Coordinate relationships in the supply chain	Giunipero and Eltantawy (2004)
Increase information sharing	Giunipero and Eltantawy (2004); Li et al. (2006)
Supplier selection process	Levary (2007)
Well stocked pipeline	Zsidisin, Panellu and Upton (2000)
Supply chain reengineering	Christopher and Peck (2004)
Create a supply chain disruptions management culture	Christopher and Peck (2004)

On the other hand, it is also worth mentioning that there are studies addressed to supply disruptions but from the recovery perspective. Ivanov et al., (2017) propose inventory, capacity and backup suppliers as policies for supply disruptions recovery in the supply chain.

3. PREVENTIVE ACTIONS PROPOSAL TO IMPROVE THE PREPAREDNESS CAPACITY OF ER

The research methodology used in this paper consists of three main steps as it is shown in Figure 1. These steps define the procedures used to shape the preventive actions proposal whose main objective is to support companies to improve the preparedness capacity of ER.

Step 1. Identification of the critical disruptive events related to the supply side. An exhaustive literature review is performed to identify the most mentioned supply disruptive events that cause companies concern. The bibliographic sources used in the literature analysis are of two different nature. On a first hand, scientific articles are studied based on a systematic literature review. To do so, combinations of the following keywords are used: “supply”, “chain”, “resilience”, “disruptions”, and “disruptive events”. The search is done in Elsevier’s Scopus publication database (abstract, title and keywords) considering 10 years from 2008. However, not too many evidences are found. For this reason, alternative bibliographic sources are considered. In this case, a systematic mapping study is used and the alternative sources are focused on reports developed by consulting firms that every year perform surveys to study the disruptive events that keep most business up at night. Multinational professional

services entities such as Deloitte, Ernst & Young, Price Waterhouse Cooper,... are the main information sources (from 2008 – 2019) to recognize real current critical disruptive events.

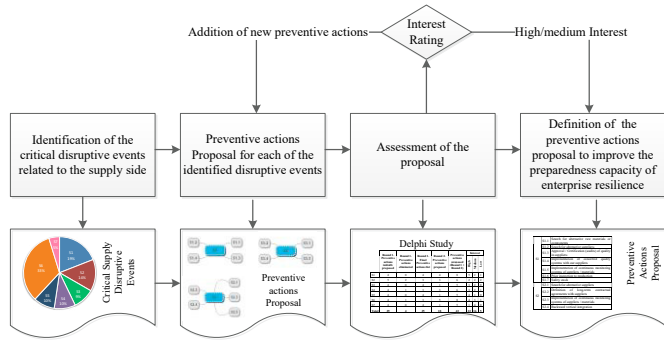


Fig. 1. Research Methodology for the definition of the preventive actions proposal to improve the preparedness capacity of ER

Table 2 shows the enumeration of the review findings. The following seven events are identified critical because they seriously and/or frequently affect the normal enterprise operation:

- S1. Poor quality of the raw materials or components supplied.
- S2. Limiting changes in the capacity of suppliers.
- S3. Geographic dispersion of our suppliers (time difference, language, proximity, inequality).
- S4. Delay in the supply of raw materials or components.
- S5. Shortage/Scarcity of raw materials.
- S6. Price fluctuations of the materials supplied.
- S7. Withdrawal of a key supplier.

Table 2. Critical supply disruptive events identified in the literature review.

	BDO (2008)	EG (2008)	WEC (2012)	DEL (2013)	WEC (2014)	BCI (2015)	E&Y (2015)	AON (2017)	BCI (2018)	WEC (2019)
S1	✓			✓		✓			✓	
S2						✓			✓	✓
S3	✓									✓
S4						✓			✓	
S5								✓		
S6	✓	✓	✓		✓		✓	✓	✓	✓
S7									✓	

Moreover, from the systematic literature study based on scientific articles, events S2, S3, S5 and S6 are mentioned in Pettit, (2008); S7 is found in Madni and Jackson (2009); S2, S5 and S6 are addressed in Pettit, Fiksel and Croxton (2010). Finally, the investigation of Barroso, Machado and Machado (2011) is focused on events S1 and S4. In light of this, the disruptive event most cited in the literature review is event S6 related to the changing prices of raw materials and components. This disruptive event appears in 31% of the information sources reviewed. The second events most cited is S1 and related to quality problems of the supplied materials and the limited capacity of suppliers respectively with a 16% of appearance in the different checked sources.

Step 2. Proposal of preventive actions for each of the identified disruptive events. Once that the most critical disruptive events related to the supply side have been identified, the following step is to propose mitigation policies, as preventive actions, to anticipate and face the negative effects of a disruptive event occurrence. This step is carried out based on the literature review and interviews with academics, researchers and professionals of companies belonging to sectors such as textile, plastic injection, construction... With all the information collected from both information sources, a preliminary list of preventive actions is shaped. On average, for each disruptive event, four preventive actions are proposed. In total 29 preventive actions are defined (disruptive event S2 has 5 preventive actions proposed). Some of the preventive actions proposed to mitigate a particular disruptive event are also defined to mitigate another one as they can be applied in different situations. For example, one of the preventive actions proposed is: “safety stock” and this preventive action has been defined for two disruptive events S1 and S4 to try to keep from occurring in both cases. For this reason, from the total of 29 preventive actions, there are only 15 exclusive.

Step 3. Assessment of the proposal. In order to validate the proposal developed in step 2, a Delphi study is performed. A Delphi study is a technique whose main objective is to obtain the consensus of a group of experts (Dalkey and Helmer, 1963 and Turoff, 1971), this is the reason why the Delphi study is understood as a group decision technique. It is an iterative process that gathers the anonymous judgment of experts using data collection and analysis techniques followed by a controlled feedback (Skulmoski, Hartman and Krahn 2007). Authors such as Okoli and Pawlowski (2004) consider the Delphi study, as a relevant method, for theory building, so that the results are linked to the theoretical basis and their practical contribution is demonstrated.

Astigarraga (2003) enumerates the Delphi method in 4 phases: (i) formulation of the problem, (ii) choice of experts, (iii) preparation and launching of questionnaires and (iv) practical development and exploitation of results.

Table 3. First round of the Delphi study results.

	Preventive actions proposed	Interest			New preventive actions proposed by experts
		High	Medium	Low	
S1	4	3	1	0	4
S2	5	1	2	2	1
S3	4	2	2	0	1
S4	4	2	1	1	2
S5	4	3	1	0	1
S6	4	0	3	1	4
S7	4	0	4	0	1
Total	29	11	14	4	14

In light of this, a questionnaire is prepared. The questionnaire includes the 7 disruptive events identified in step 1 and the proposal of preventive actions for each of the disruptive events. The questionnaire has a 3-point Likert scale, where experts have to indicate the interest of each of the preventive

action proposed (high, medium or low interest). Besides this, experts are also invited to add new interesting preventive actions for each of the disruptive event. The questionnaire was answered by 12 experts with different background and from different countries (France, Spain, Switzerland, and UK). Moreover, such experts belong to different fields: research, academia and business/industrial areas. Their main knowledge domains cover a wide range of disciplines such as supply, resilience, risk, from an enterprise and supply chain viewpoint. Table 3 shows the results obtained in the first round of the Delphi study.

After the experts' assessment, the preventive actions classified as low interest, that were the 14% of the proposed ones, were eliminated from the proposal and a new questionnaire with the new preventive actions proposed by experts was launched again in a second round. The results obtained in this second round are shown in Table 4.

Table 4. Second round of the Delphi study results.

	Round 1			Round 2	Round 1 + Round 2	Interest		
	Preventive actions initially proposed	Preventive actions eliminated	Final Preventive actions list	Preventive actions proposed	Preventive actions proposed	High	Medium	Low
S1	4	0	4	4	8	5	2	1
S2	5	2	3	3	6	2	2	2
S3	4	0	4	1	5	3	2	0
S4	4	1	3	3	6	3	2	1
S5	4	0	4	1	5	4	1	0
S6	4	1	3	5	8	4	3	1
S7	4	0	4	1	5	1	4	0
Total	29	4	25	18	43	22	16	5

The second round was the last iteration as experts quantify all the preventive actions again (the initially proposed in round 1– the low interest preventive actions of the first round + the new ones proposed by experts). In this second round, the percentage of the preventive actions classified as low interest was lower than in round 1, as it was 12%. Therefore, experts consider more interesting the preventive actions proposed by them than the ones initially proposed as the % of low interest is inferior in this second case. Although it is worth mentioning that the difference between the number of eliminated preventive actions in the two round is minimum.

Moreover, the analysis of the preventive actions interest per disruptive event has been studied. To do so, each of the 3-point Likert Scale has been quantified (High: 3; Medium: 2; Low interest:1). Based on this, Fig. 2 shows the results obtained. The disruptive event S5: "Shortage of raw materials" is the one that presents the preventive actions more interesting according to the experts' assessment in the Delphi study. The disruptive event S3: "Geographic dispersion of our suppliers" is the second one that more high interest preventive actions have been defined followed, in third place, by the ones of the disruptive event S1: "Poor quality of the raw materials or components supplied".

Step 4. Definition of the preventive actions proposal to improve the preparedness capacity of ER. The high and medium interest preventive actions assessed by experts through the Delphi study have been considered as appropriate to be included in the present proposal. Not all the disruptive events have the same number of preventive actions, on average each disruptive event has 5.5 preventive actions defined. Table 5 shows the different preventive actions proposed to enhance the preparedness capacity of ER.

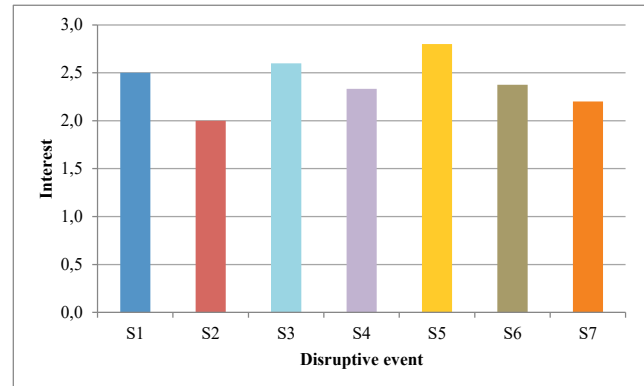


Fig. 2. Average quantification of the interest of the preventive actions per disruptive event

Table 5. Preventive actions proposal from a supply side

S1	S1.1	Search for alternative raw materials or components
	S1.2	Search for alternative suppliers
	S1.3	Approval / Certification (audits) of quality in suppliers
	S1.4	Implementation of concerted quality systems with our suppliers
	S1.5	Implementation of continuous monitoring systems of suppliers / materials
	S1.6	Prior inspection to production
	S1.7	Safety stock
S2	S2.1	Search for alternative suppliers
	S2.2	Definition of long-term contractual agreements with suppliers
	S2.3	Implementation of continuous monitoring systems of suppliers / materials
	S2.4	Vertical backward integration of part or all of the supply function
S3	S3.1	Search for alternative suppliers
	S3.2	Promotion of closer relationships
	S3.3	Implementation of real-time communication systems
	S3.4	Implementation of continuous monitoring systems of suppliers / materials
	S3.5	Encourage a common culture and argot for the entire supply chain
S4	S4.1	Implementation of penalties for delay
	S4.2	Search for alternative suppliers
	S4.3	Encouragement of collaborative work with suppliers and joint problem solving to establish realistic replenishment systems
	S4.4	Implementation of continuous monitoring systems of suppliers / materials
	S4.5	Safety stock
S5	S5.1	Search for alternative raw materials or components

	S5.2	Definition of products' new compositions
	S5.3	Definition of complementary products that do not require the scarce raw materials and replace the current products
	S5.4	Implementation of Research, Development and Innovation operations to replace the existing raw materials by other complementary
	S5.5	Implementation of reverse logistics and recycling systems
S6	S6.1	Analysis of the seasonality and trend (supply-demand balance) of raw materials prices
	S6.2	Search for alternative raw materials or components
	S6.3	Search for alternative suppliers
	S6.4	Definition of long-term contractual agreements with suppliers
	S6.5	Vertical backward integration of part or all of the supply function
	S6.6	Negotiation with suppliers
	S6.7	Close monitoring of commodity markets. Strategic purchases
S7	S7.1	General increase in the supply base
	S7.2	Partnership with suppliers (temporary union of companies ...)
	S7.3	Search for alternative suppliers
	S7.4	Implementation of continuous monitoring systems of suppliers / materials
	S7.5	Vertical backward integration of part or all of the supply function

This proposal is a first attempt to improve the preparedness capacity, as constituent capacity of ER, from the supply side, by implementing, or at least evaluating, the different mitigations alternatives defined. For example, a specific company is very worried about the disruptive event S5: “shortage of raw materials” since currently there are some warning signals indicating that in the near future there will be scarcity of the raw materials they use for their products. This company can consult the present proposal to find the different alternatives to be implemented before the imminent occurrence of the disruptive event. For each one, the company should assess the implementation cost but also analyse the benefits and/or utility that will obtain after its implementation. This will be considered in further research.

4. CONCLUSIONS AND FURTHER RESEARCH

Enterprises should be resilient enough to face the current environment uncertainty and risks. ER is a capacity that requires to be prepared for the unexpected, to adjust efficiently to the changes and to recover appropriately once that the enterprise is impacted by a disruption. One of the constituent capacities of the ER is the preparedness with which enterprises have to foresee and advance disruptions. Therefore, enterprises should be observant about their surroundings to detect potential disruptions that can impact negatively. However, it is not sufficient to be vigilant, it is also necessary to implement preventive actions that enhance the preparedness capacity of ER. In light of this, the present paper presents an analysis focused on the supply side and provides valuable information about the most critical disruptive events that can affect enterprises. Moreover, it offers a mitigation proposal composed by a set of preventive

actions to be implemented in order to enhance the preparedness capacity of ER. This is the seminal and first approximation in order to shape the mechanisms that allow companies to assess how exposed are to threats, and based on this analysis, take the right decisions about what preventive actions should be implemented to diminish its risk exposition.

Further research will be focused on implementing and validating this proposal in different real cases: a textile SME and a large company belonging to the automotive sector, both from Spain. However, this proposal still lacks the definition of indicators and a mechanism to assess the preparedness capacity of ER. For this reason, further actions will encompass the following activities:

- To evaluate the current situation of an enterprise (AS IS model) according to the disruptive events identified previously. To do so, indicators (frequency, severity...) should be defined to assess how vulnerable enterprises are when facing the different disruptive events identified.
- Based on the aforementioned analysis, to select the most adequate preventive actions proposed. To do so, enterprises will also need indicators to quantify the optimal selection of preventive actions. Moreover, mathematical modelling will be necessary to obtain the optimal solution.
- To evaluate the future situation (TO BE model) after implementing the optimal set of preventive actions based on the mathematical model solution. This evaluation will be focused on two directions. The first one should be addressed to assess the implementation cost and the second one should evaluate the enhancement level of the preparedness capacity to achieve a trade-off between cost and enhancement level.
- To extend the analysis performed in this paper to other disruption sources such as customers, natural circumstances, logistics, technological issues, social aspects, among others... to build a complete framework with the most critical disruptive events that seriously worry current enterprises.

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