

Literature review about supply chain vulnerability and resiliency

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Abstract: - This paper focuses on the literature review regarding the vulnerability of supply chains and the relative resiliency. After identifying the most common threats (that can have high or low probability of occurrence) that affect the supply chain integrity, some best practices from real cases are provided in order to provide the key factors to build a resilient supply chain. This research represents the basis for a future work, that will end up with the elaboration of a System Dynamics model that will provide insight regarding the dynamics of short life cycle products, such as fashion goods or electronic devices, with the goal of proposing innovative solutions.

Key-Words: - vulnerability, resiliency, risk management, supply chain,

1 Introduction

Interruptions in ports, customs and transportation delays or capacity constraints are only some of the problems, at a global level, that companies must face every day. Moreover, in the last years, catastrophic events such as the terrorist attacks of September 11 in 2001, the Katrina hurricane or the Middle East wars sensibly modified the concept of preparation to disasters.

In the current uncertain and turbulent markets, the supply chain vulnerability has become a particularly important issue for many companies.

The threats to the supply chain have been indeed sharpened by long and global supply chain, by products with increasingly reduced life cycles and by volatile and unpredictable markets.

Unfortunately it does not exist a safe way to overcome these risks, but some organization overcomes better than others not quantifiable risks and symptoms. They share a critic characteristic: the resilience.

So, the challenge for current companies is to manage and mitigate these risks through the creation of more resilient supply chains, able to opportunely and efficaciously face unexpected events.

In the material science, the resilience represents the ability of a material to reacquire its original shape after a deformation, while, in the business sector, resilience refers to the ability of a company to resist to a serious damaging event.

A company ability to come back to its business after a catastrophe depends more on the decisions and actions that it carries out before the shock occurrence rather than on those that it puts into place after or during the event. Moreover the resilience is not a problem at the company level but at the supply chain level, since a company can suffer damage not only when one of its plant is concerned, but also if crucial supplier ability is destroyed or if a big customer fails. Finally, supply chain resilience does not simply imply the ability to manage risks, but also to be better placed with respect to the competitors in the damage management – and even to take advantage from it.

2. Supply chain vulnerability

Bjørn Egil Asbjørnslett and Marvin Rausand in 1997 [1] define the vulnerability concept as it is applied to the production systems: “A strong and resilient system is able to support without perturbation or absorb a catastrophic failure and persist”.

Strong means that it is able to resist to an unexpected event and to come back in the same steady situation. Resilient means, on the contrary, able to come back in a new (often "inferior") steady situation with respect to that subsisting before the event. In other words, a strong system will maintain intact its structure, while a resilient system shall adapt itself to find a new steady position. In a business, the capacity to survive (resilience) is much

more important than the ability to rapidly recover the steadiness (strength).

A resilient company is able to better support the unpredictability of the global trade obtaining a competitive advantage, being able to make up more quickly than the competitors when a catastrophe hit it.

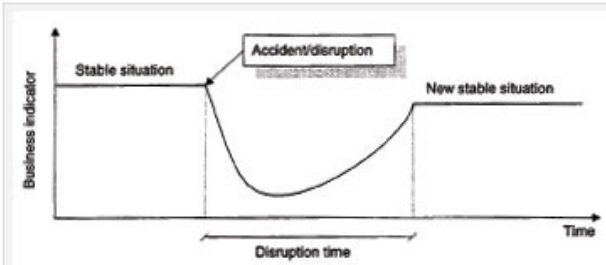


Fig. 1. Regaining stability after an accident/disruption

Disruption profile, from: Asbjørnslett (1997)

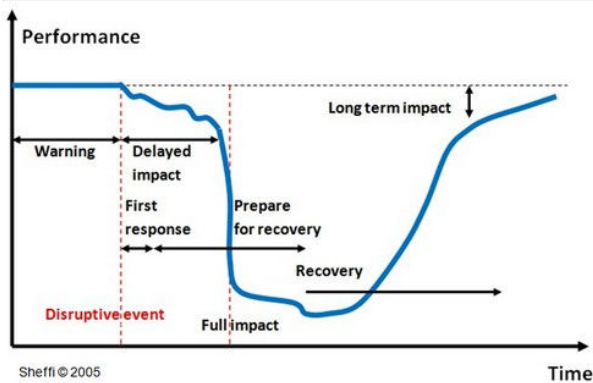


Fig.1 A damaging event profile

Source: Asbjørnslett & Rausand, "Assess the vulnerability of your production system"[1] and Sheffi "The resilient enterprise"[2]

The two schemes displayed in Fig.1, very similar each other, are the profiles of a damaging event according to Asbjørnslett (figure above) and according to Yossi Sheffi (figure below). They represent what occurs when the supply chains suffer an accident. The companies can - or not - be able to come back to the situation in which they were before the event occurrence. The company survival depends only on the company resilience with respect to the event.

A vulnerability analysis is not equivalent to a risk analysis. The latter focuses on human resources, on environmental and property impacts of an accidental event, while a vulnerability analysis is focused on the system survival (Fig.2).

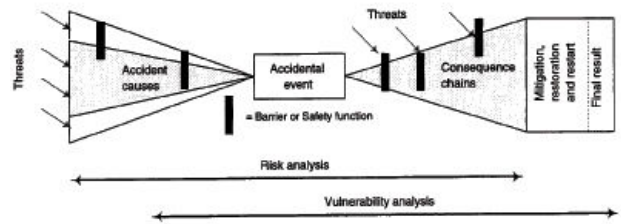


Fig. 5. Difference in scope between vulnerability analysis and risk analysis

Risk analysis vs. vulnerability analysis, from: Asbjørnslett (1997)

Fig.2 Difference between risk and vulnerability analysis.

Source: Asbjørnslett & Rausand, "Assess the vulnerability of your production system"[1]

A vulnerability analysis is focused on:

1. a wide range of threats and consequences;
2. suitable resources to face the event and bring back the system towards a new stability;
3. the interruption length of time before that the new stability is re-established.

Clearly, the vulnerability analysis has a wider range with respect to the risk analysis. Particularly the first concerns the way to weaken the detected threats and start again the system after an accidental event.

Asbjørnslett and Rausand describe the steps to carry out a vulnerability analysis. Firstly, it is developed an evaluation scenario, with the list of threats and the potential risk scenario probability. Secondly, it is carried out a previously detected factor quantitative analysis, classifying threats and scenarios according to the criticalities in terms of impacts on human resources, environment, trade and real estates. Thirdly, the threats are displayed in a vulnerability matrix, as shown in Fig.3.

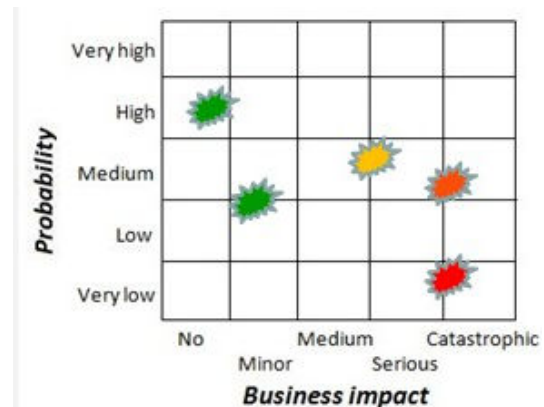


Fig.3 Example of vulnerability matrix

Source: Asbjørnslett & Rausand, "Assess the vulnerability of your production system"[1]

The fourth step consists in taking the great part of critical events in the vulnerability matrix and list how they should be faced, so as to reduce a) the probability that these events can occur and b) the consequences in the case they should occur.

In “The Resilient Enterprise” [2] Yossi Sheffi, Professor of System Engineering and Director of the “Center for Transportation and Logistics” of the MIT of Boston, analyses the high impact/low probability destructions. Sheffi states that in the process towards a resilient organization creation, companies must at first detect and create a priority of the risk typologies and levels they must face. As Fig.4 shows, it is possible to classify the consequences deriving from a perturbation as a function of the event occurrence probability (high or low) as well as of the impact level (more or less serious).

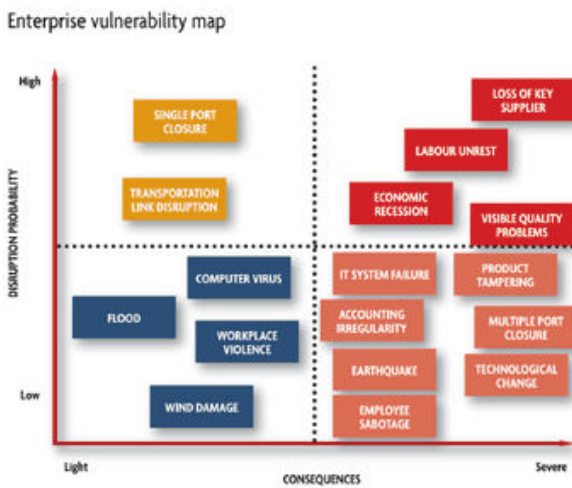


Fig.4 Enterprise vulnerability map
Source: “The resilient enterprise” [2], page 32

The companies must face also low probability/high impact events, which are intentional. They include not only terrorist attacks, but also strikes and sabotages. These perturbations can hit in the worst moment and in the worst place, since they are conceived to inflict the greatest damage.

Martin Cristopher, in [3], gives the following definition of supply chain vulnerability: "an exposition to serious perturbations, deriving by risks inside the supply chain, as well as to risk outside the supply chain". The distinction between supply chain inner and outer risks, according to Christopher, is artificial. In the Northern America, the emphasis regarding the event of September 11th 2001 was focused on the outer risks, and particularly on the needs and implications of the anti-terrorist measures implemented by the United States authorities, as well as their impact on the domestic business and international trading. In the Academy, on the

contrary, the interest on the supply chain inner risk study is increasing, mainly above all about the manufacturing industries [4]. The supply chain risks can be classified in very different ways and by different perspectives, as shown in Fig.5. Inside the enterprise, there are a “process” and a “control” risk; outside the enterprise but inside the supply chain there can be identified a network risk, divided in “demand” and “supply”. Finally, outside the network, there is a “environmental” risk.

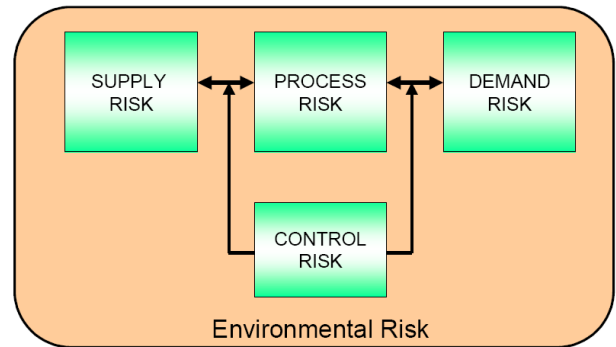


Fig.5 Risk sources in the Supply Chain
Source: “Shrinking the Supply Chain Uncertainty Cycle”, [5]

Among the inner risks, there are those relevant to the processes, which are sequences of added value and management activities undertaken by the company; the process risk refers to these process interruptions.

The controls are the engagement, the standards, the systems and the procedures used by an organization to exert its control on processes. The control risk is therefore relevant to the risk deriving from the wrong application of these standards.

As concern, on the contrary, the company outer risk, those relevant to the demand refer to the potential or real damage with respect to the product, the information and the money flow between the company and the market.

The supply risk is the equivalent of the previous one, with the difference that it refers to the potential or real perturbation of the product/information/money flow coming from the company upward.

The fifth and last category concerns the interruptions which are outside the organization network belonging to the supply chain. With the “environment” risk we refer then to the event, which can directly impact on the same company, they could be socio-political, economic or technologic events, which have not to do with the concerned company supply chain, but whose effects can have repercussions on it.

3.How to build up a resilient organization

Becoming more resilient, the enterprises can sensibly mitigate the risks they are subjected to.

In the literature, Martin Christopher [6] and Yossi Sheffi [2] provided the main reference schemes concerning resilient organization building modes.

3.1. The resilient supply chain according to Martin Christopher

The scheme shown in Fig. 6 displays the elements constituting a resilient supply chain according to Christopher.

The “supply chain re-engineering” requires:

- A deep understanding of the network connecting the business to its suppliers and customers and the detection of the bottlenecks and the so-called critical paths of the same.
- The definition of a supply strategy, which should preferably not be based on a single supplier, but rather on a reliable supplier with other supply possible alternatives.
- The choice of supply chain strategies keeping into consideration different options.
- The “efficiency” versus “redundancy” trade off re-examination. An inventory maintenance or, better, a capacity surplus, if on one side it contributes to the cost increase, on the other allows to manage more efficiently the uncertainty related to the demand and the offer;

Another important point is to support the cooperation along the supply chain. It is necessary to work in partnership since the information exchange can remarkably reduce the uncertainty allowing identifying the risk and uncertainty sources relevant to each node and link in the supply chain.

Christopher focuses also on the supply chain agility, defined as the ability to rapidly respond to unforeseen changes in the demand and supply; agile partners upward and downward of the enterprise are required.

The last aspect focused by Christopher regards the creation of supply chain risk management culture. Moreover, as in any case of enterprise cultural changing, nothing is possible without a strong leadership by the company top management.



Fig.6 How to create a resilient supply chain

Source: “Building the resilient supply chain”[3]

3.2 The resilient supply chain according to Yossi Sheffi

Yossi Sheffi has provided another resilient supply chain model with a set of tools to build it, in his volume “The resilient Enterprise” [2].

Sheffi underlines that the company risk management shows itself under 3 forms: there are the managers dealing with the business continuity plan drawn up, there is the safety staff (badge for the access, safety codes, etc) and finally the information technology safety function (for instance Data back up).

Therefore these 3 functions are often stand-alone and they cannot be integrated in the company strategies. The traditional definitions of business safety and continuity are only a small part of the real resilience. In particular, according to the MIT Professor, the companies can develop the resilience mainly in three ways: increasing the redundancy, building the flexibility and changing the company culture. The first has a limited utility; the other two on the contrary result to be essential.

A first key of resiliency is “redundancy”. Theoretically, a resilient company can be created by generating redundancies along the supply chain. The organization can maintain extra stock, a low exploitation capacity, many suppliers, etc. Therefore, even if the redundancy can supply an accumulation to continue to operate after damage, typically this is a very expensive temporary measure.

Another success factor is “flexibility”. On the contrary, when a company increases the supply chain flexibility, it can resist both to significant damages and face at the best the demand fluctuations.

To reach an “intrinsic” flexibility, a company should undertake the following actions:

- Adopt standardized processes, (i.e. displace the production among the plants using the generic and interchangeable parts in many products)
- Use concurrent processes instead of sequential. Exploit simultaneous processes instead of sequential in some key areas, such as the product development and the production/distribution, accelerates the recovery phase after damage and gives collateral benefits to better respond to the market.
- Plan to postpone, planning products and processes using the “maximum postponement/delay” logic for as much operations and decisions as possible along the supply chain. Maintaining the products in a semi-finished state guarantees indeed the flexibility to displace the products from surplus zones to areas showing a deficit.

Benetton, for instance, re-planned its production processes such in a way that many products, above all those subjects to a high demand variability, are manufactured in a generic way and are finished only when the company acquires information about the demand.

- Align the supply strategy to the relationships with the suppliers. There are two main orientations:
 1. If a company relies on a small group of key suppliers, it must maintain a deep relationship with each of them.
 2. On the other side, if a company is not strongly allied with a supplier group, its supply network, in order to be resilient and reactive with respect of the market, should be able to enjoy a greater extension. Then, maintaining a wide range supplier network distributes the risk in case of damage occurrence.

No one of the two strategies is necessarily correct; the problem is to choose the approach aligning the company supply relationships of a with its supply strategies.

The other key factor devoted to achieve resiliency is the “Cultural Change”.

After an interruption, the factor that clearly distinguishes those companies rapidly recovering, and even with a profit, from those, which are unsteady, is the company culture, which can be helped and improved thanks to:

- Continuous communication among informed employees. It is necessary indeed to keep the employees informed about the strategic targets, the tactic factors and the business changes day by day and minute by minute. The Dell employees have the continuous access to the product production and, forwarding data as well as to a wide range of other information, when a damaging event occurs, the employees know the company state (which are the sales, where are the raw materials, etc.) and can use this knowledge to take better decisions to face the unforeseen event.
- Distributive power. Another important resilience principle is to confer power, in the decisional processes, to all the company employees. Before that a potential damage is visible by the manager, those that are invested with responsibility and “close to the action” can take the necessary measures. Zara and World – two retailers, respectively with their head office in Spain and Japan, – are extraordinarily able to confer power to the employees. In both companies, a shop responsible each evening collect information not only about the good sold and not sold, but also on the reason for which some goods has not been sold out.
- Work passion. The successful companies arise in their employees the passion for the work they carry out. Moreover in the resilient companies there is always passion for work. The passion begins with the whole company mission understanding, feeling a part of the mission and believing in it.

For those companies operating in extremely uncertain markets, such as those of the consumption electronics, the high-tech or fashion, the product changing rate is so rapid that the uncertainty in terms of demand is very high. They must plan a reactive supply chain devoted to satisfy the market demands and, at the same time, do not find themselves with a warehouse surplus.

3.3 The supply chain resilience according to other authors

Martin Christopher and Yossi Sheffi, are not the only ones who have faced the supply chain resilience study.

For example Christopher S.Tang, in [7], starting from the remark that many companies, in the optic to obtain advantages of costs and market shares, implement different initiatives – such as the outsourcing or the production of many different products – which can lead to a more vulnerable

supply chain, carries out a review of different quantitative models used to manage the supply chains, including those proposed by the literature.

According to Christopher Tang and Brian Tomlin ([8]) the alignment, the adaptability and the agility are the basic ingredients for the risk management in the supply chain. While it is clear that the flexibility (agility) improves the supply chain resilience, it is not clear how much flexibility is necessary to mitigate the risks. The authors show models devoted to illustrate that the companies can obtain a significant strategic advantage by implementing a risk reduction program requiring a relatively low flexibility level.

In [9] Oke and Gopalakrishnan investigate the risk typologies faced by the supply chain of a big American distributor and how to manage them. The authors classify the frequent and not frequent risks and analyze the mitigation strategies to face these risks aiming to detect the general strategies able to manage the great part of the risk typologies, as well as the specific strategies for the particular risk management.

Finally K.Mitra et al. in [10] show, on the contrary, a multi-site, multi-product and multi-period supply chain planning problem formulation implementing a fuzzy mathematical planning approach and analyzing the impact of different factors of uncertainty, such as those relevant to the product demand, the machine times and the cost components of the different products.

4. Conclusion and further developments

Worldwide phenomena such as globalization and production delocalization, together with low probability/high impact events such as terrorist attacks, have exposed supply chains to bigger risks and damages in respect to the past. For these reasons, the need of building resilient supply chains devoted to better resist to the impact of both internal and external vulnerabilities has become a priority for companies.

This work regards the literature review about the vulnerability and resiliency of supply chains. Some authors have provided different solutions in order to face properly this matter, reporting also some successful companies' best practices.

In the near future, the authors will focus their attention on how to create resilient supply chains for short life cycle products, by implementing a System Dynamics model.

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