

# Objectives and perspectives for improving resiliency in Supply Chains

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*Abstract:* - This paper aims at providing the key aspects regarding vulnerability of supply chains and the way to make them more resilient. After having identified the most common threats affecting supply chains integrity, the success factors to build a resilient supply chain are provided. For instance, in the fashion goods context, particular phenomena cause unpredictable behaviours in the demand, so generating vulnerability in the relative supply chain. A KPIs methodology for studying the behaviour of these supply chains under these phenomena is proposed.

This research represents the basis for a future work that will end up with the elaboration of a System Dynamics model able to reproduce the most significant dynamics of short life cycle products, such as electronic devices, with the goal of providing innovative solutions to make this kind of supply chains more resilient.

*Key-Words:* - Vulnerability, Resiliency, Risk Management, Supply Chain, KPIs, Fashion goods.

## 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 decade, 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.

So, in the current uncertain and turbulent markets, supply chain's vulnerability has become a particularly important issue for many companies. Threats to the supply chain have been deeply increased by long and global supply chains, products with increasingly reduced life cycles and volatile and unpredictable markets.

Unfortunately it does not exist a safe way to overcome these risks, but some organizations overcome better than others not quantifiable risks and disasters; they share a critic characteristic: the resilience.

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

In material science, 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 is occurring. Moreover the resilience concept not only affects the company level but the whole supply chain, since a company can be damaged not only when one plant is concerned, but also if a crucial supplier cannot supply materials or if a big customer goes bankrupt. Finally, supply chain's resilience does not simply imply the ability to manage risks, but also to be better placed in respect to competitors towards the management of the damage – and even to take advantage from it.

## 2. Supply chain vulnerability

Bjørn Egil Asbjørnslett and Marvin Rausand in 1997 [1] defined the vulnerability concept as it is applied to production systems: “A strong and resilient system is able to support without perturbations 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 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 its steadiness (strength).

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

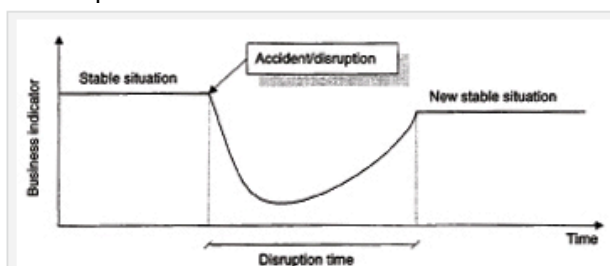


Fig. 1. Regaining stability after an accident/disruption

Disruption profile, from: Asbjørnslett (1997)

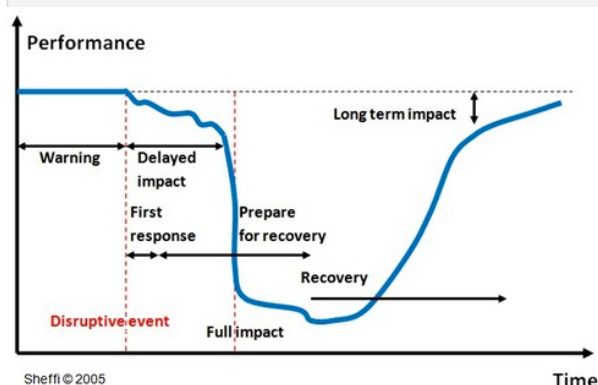


Fig.1 A damaging event profile

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 between them, are the profiles of a damaging event according to Asbjørnslett (figure above) and to Yossi Sheffi (figure below). They represent what occurs when a supply chain suffers an accident. The company can - or not - be able to come back to

the situation in which it was before the event occurred; in any case the company survival depends only on its level of resilience.

Sometimes vulnerability analysis is confused with risk analysis; however the latter focuses on human resources, environmental and property impacts of an accidental event, while the former regards the system survival (Fig.2).

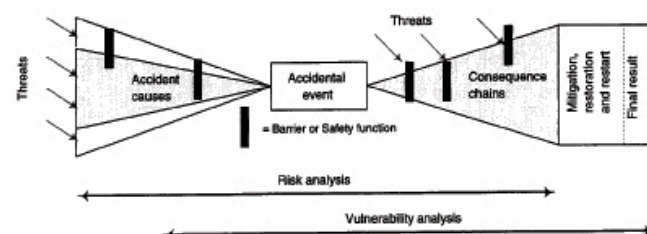


Fig. 5. Difference in scope between vulnerability analysis and risk analysis

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 focuses on:

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

Asbjørnslett and Rausand have described the steps to carry out a vulnerability analysis. Firstly, some scenarios are developed, with the list of all the threats and the relative probabilities to occur. Secondly, a factors quantitative analysis is implemented, 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.

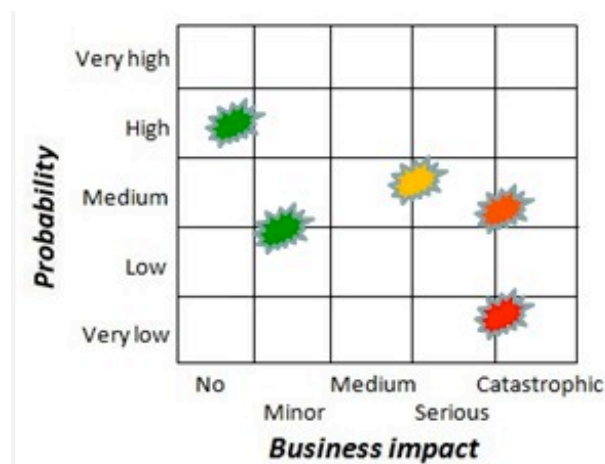


Fig.3 Example of vulnerability matrix

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 would 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 the creation of a resilient organization, companies must at first detect and create a priority of the risks typologies and entities 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).

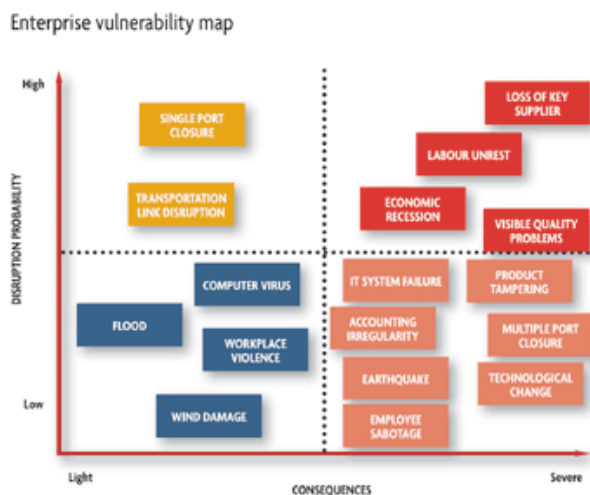


Fig.4 Enterprise vulnerability map

Source: "The resilient enterprise" [2], page 32

In fact, companies must face not only high probability/low impacts events, such as the closure of a port, but also low probability/high impact ones, among which there can be included terrorist attacks, strikes or 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 by risks outside it". The distinction between inner and outer risks, according to Christopher, is artificial. In Northern America, the emphasis on the event of September 11<sup>th</sup> 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 University and Research field, on the contrary, the interest on the supply chain inner risk study is increasing, mainly regarding manufacturing industries [4]. Supply chain risks can be classified in very different ways and by different perspectives, as shown in Fig.5. According to [5], inside an enterprise, there are a "process" and a "control" risk; outside the company 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.

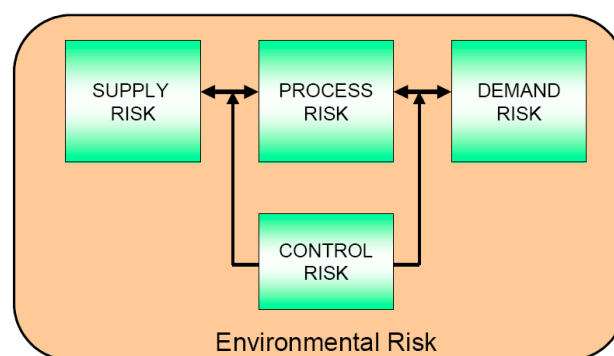


Fig.5 Risk sources in the Supply Chain

Source: "Shrinking the Supply Chain Uncertainty Cycle", [5]

Process risks refer to company processes' interruptions. "Controls" mean all the standards, systems and procedures used by an organization to exert its control on processes. The control risk is therefore the one deriving from the wrong application of these controls.

With regard to the company outer risks, those relevant to the demand refer to the potential or real damage with respect to products, the information and money flowing between the company and its market. The supply risk is instead equivalent to 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 - "environment" risk - concerns events occurring outside the organization network but that have an impact on the company supply chain. Examples of these events are socio-political, economic or technologic facts (such as a strike or Internet interruption), 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, enterprises can sensibly mitigate the risks they are subjected to.

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

#### 3.1. A 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;
- 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 “efficiency” versus “redundancy” trade off re-examination. Holding an inventory or, better, a capacity surplus, if on one side contributes to increase costs, on the other side, allows to manage more efficiently the uncertainty related to demand and 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 uncertainties connected 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 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 coming from the company top management.

Figure 6 summarizes the key aspects provided by Christopher to create a resilient supply chain.



Fig.6 How to create a resilient supply chain

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

#### 3.2 A resilient supply chain according to Yossi Sheffi

The hereafter it will be described the suggestions and ideas about how to create a resilient supply chain provided by Yossi Sheffi, in his volume “The resilient Enterprise” [2].

Sheffi underlines that a company risk management function shows itself under three forms: there are managers dealing with the business continuity plan drawn up, there is the safety staff (badge for accesses, safety codes, etc.) and finally the information technology safety function (in charge for instance of the data back up). These three functions are often stand-alone and are not integrated in the company strategies. This puts into evidence that the traditional definitions of business safety and continuity imply only a small part of the real company resilience. In particular, according to the MIT Professor, companies can develop resilience mainly in three ways: increasing redundancy, building flexibility and changing the company culture. The first has a limited utility; the other two components, 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 of capacity, many suppliers, etc. However, even if redundancy can supply an



accumulation to continue to operate after damage, typically this is a very expensive temporary measure.

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

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

- Adopt standardized processes, i.e. displace the production among the various plants utilizing generic and interchangeable parts in many products.
- Use concurrent processes instead of sequential ones. Exploit simultaneous processes instead of sequential in some key areas, such as product development or final distribution, accelerates the recovery phase after damage and gives collateral benefits to better respond to the market.
- Plan to postpone, that means planning products and processes using the “maximum postponement/delay” for as much operations and decisions as possible along the supply chain. Maintaining products in a semi-finished state guarantees indeed the flexibility to move 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 more precise information about the demand.
- Align the supply strategy to the relationships with 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 to the market, it should be able to enjoy a greater extension. Then, maintaining a wider 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 strategy with its suppliers ‘one.

Another key factor devoted to achieve resiliency is “cultural change”. As a matter of fact, after a disruptive event, the factor that clearly distinguishes those companies rapidly recovering -

even with profitability - from those which succumb, is the company culture, which can be helped and improved thanks to:

- Continuous communication among informed employees. It is necessary to keep employees informed about the strategic targets, the tactic factors and the business changes day by day and minute by minute. Dell employees have continuous access to products manufacturing data as well as to a wide range of other kind of information; so, when a damaging event occurs, employees perfectly know the company state (which is the actual trend of sales, where raw materials are, 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 managers, 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 their employees. In both companies, shop responsible, each evening, collect information not only about the goods sold and not sold, but also on the reason for which some goods has not been sold out. This information are sent real time to the head office, which can therefore quickly identify possible risks or problems along the supply chain.
- Work passion. Successful companies transfer to their employees passion for the work they carry out. In resilient companies there is always passion for work. Passion arises when the whole company mission is understood, feeling a part of the mission and believing in it.

For those companies operating in extremely uncertain markets, such as those working in the field of consumption electronics, high-tech or fashion, product changing rate is so rapid that the uncertainty in terms of demand is very high. So, they must plan a reactive supply chain devoted to satisfy in any moment market demand and, at the same time, do not find themselves with a too high 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 study of supply chain resilience.

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, implemented different initiatives – such as outsourcing or production of many different products – which can lead to a less vulnerable supply chain. They carried out a review of different quantitative models used to manage supply chains, including those proposed by the literature.

According to Christopher Tang and Brian Tomlin ([8]) alignment, adaptability and agility are the basic ingredients for 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 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 frequent and not frequent risks and analyze the mitigation strategies to face these risks aiming to detect general strategies able to manage the great part of the risk typologies, as well as specific strategies for particular risks' management. Finally K.Mitra et al., in [10], show 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 product demand, machine times and cost components of the different products.

#### 4. Vulnerability and resiliency in the fashion field

The authors, in cooperation with experts in the Supply Chain and IT (Information Technology) fields, have studied two common phenomena that resilient supply chains have to successfully deal with in the context of fashion - and electronic - goods: the so called “Depreciation-Motivation” and the “Highlander Must Have” phenomena. Both of them provide unpredictability in demand and so they represent a big source of vulnerability for supply chains that have to face with this kind of products.

##### 4.1. The “Depreciation-Motivation” phenomenon

According to the “Depreciation-Motivation” effect, people are encouraged to buy a particular item because of special promotions on it at the end of its life cycle.

Due to the current bad economical conjuncture, many customers are discouraged to buy fashion products even if considered status symbol, trendy, with the best quality, etc. However the depreciation due to the obsolescence of this kind of products and the necessity of changing seasonal collections in shops, traduced in discounts, at the end leads to an increase in selling.

Obviously depreciation percentage should anyway be profitable, but being in many cases variable in function of obsolescence, it can be possible to define a break-even point that highlights the most convenient depreciation value for obtaining more selling, and so more profit.

Many theories have been formulated on how to calculate the break-even point and the depreciation scaling in function of time and product obsolescence; moreover each fashion player has its own rules and policies, but not to measure the effect of these actions.

To measure such effect, it would be useful to compare sales of a particular item code in the normal period and during sales times, defining a ratio: in (1),  $D_m$  represents the ratio between sales in periods in which the product has been discounted and sales when the product has been sold at its normal price.

$$D_m = \frac{\sum_{i=1}^m P_{1j} + \sum_{l=1}^q P_{2l} + \dots \sum_{w=1}^u P_{Kw}}{\sum_{i=1}^n N_i} \quad (1)$$

where:

$$\sum_{i=1}^m P_{1j} \quad (2)$$

represents the sum of sales made from day 1 to day m with the Promotion 1 (type 1 discount);

$$\sum_{w=1}^u P_{Kw} \quad (3)$$

represents the sum of sales made from day 1 to day u with the Promotion K (type K discount) and

$$\sum_{i=1}^n N_i \quad (4)$$

represents the sum of sales made from day 1 to day  $n$ , when the product has no discounts (normal sales).

To obtain the effectiveness of each discount percentage, it is possible to disaggregate the sums; even if in this case the results should be weighted by the remaining items at the beginning of the period: stock decreases during promotional actions, and at the end the hardest discounts are made when very few items remain. Indexes should in this case be referred to time and residual assortments of size/colour of the item in order to avoid errors of evaluation. It could be useful to consider each combination of size and colour as a different item, in order to evaluate more precisely the effect of the action: i.e. a black, medium size shirt of model XY is commonly more easily sold, even at full price, than an acid green extra-small size shirt of the same model XY. This should not be forgotten, because in the authors' experience, a scarce evaluation of such phenomena leads to problems of mixed packaging management in supermarket retails.

## 4.2 The “Highlander Must Have” phenomenon

The “Highlander-Must Have” phenomenon means that products with special or limited editions are characterized by a very high demand because of their rarity (everyone desires to have one of them!). With the picturesque but effective expression of “highlander”, we refer to the psychological behaviour of those customers that must have the limited-edition items most celebrated by companies' marketing.

The Swatch case is a remarkable example of this kind of phenomenon.

More than 15 years ago the low cost coloured plastic Swiss watches really became a “cult object”. However, before their launch on the market, the company was experiencing a diminishing market share due to their high-priced watches and, at the same time, to the availability of low-priced brands. In order to overcome this situation, the Swiss enterprise decided to start developing its products by using plastic cased watches instead of classy materials; the subsequent cost reduction they achieved, allowed for lower prices, thus enabling them to compete with other brands. Moreover, the production process was re-designed in order to be more efficient than its competitors and this allowed for the manufacture of cheaper products. All this enabled Swatch to boost its market share.

However after the launch of the new product on the market, the demand was higher than the expected and the supply chain/production demonstrated not

to be able to follow it, so determining a loss of sales. The reason for that must be ascribed to a wrong evaluation of the potential demand of the product or, in other words, to an under-estimation of sales forecasting. This translated in a loss of sales in the first phase of the campaign and in a “run after” the actual demand soon after. The pursuit of the demand can generate, at the end of the product lifecycle, an over stock difficult to get rid of and this represents high inventory costs and a potential loss of profit.

In the case of the company has a limited capacity compared to the entity of the market demand, it can decide to augment its capacity. However this approach is very risky because, being the time required to increase the capacity quite long (and also considering the high costs related to this operation), it can happen that by the time the capacity is being increased, the product demand is in the declining phase. So, at the end of the product life cycle, the company remains with an over capacity difficult to be exploited. This is what occurred to the hugely popular virtual pet launched in 1996 by Bandai: Tamagochi ([13]). As shown in Figure 7, realizing that the demand was dramatically boosting and being the company capacity too little to follow the demand, Bandai decided to build new capacity step by step. However, the increasing in capacity, was too limited in comparison to the demand level and by the time the life cycle curve was in the declining phase, the capacity build was useless and costly.

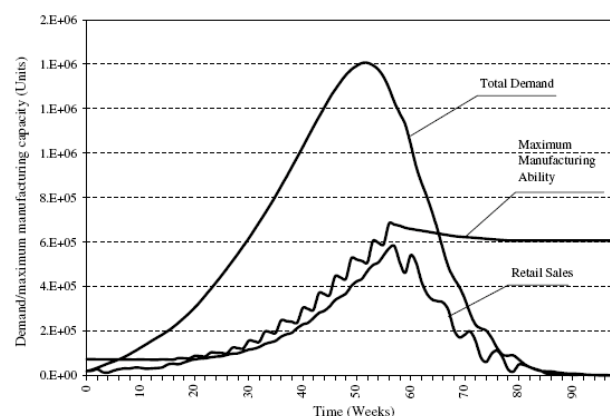


Fig. 7 Comparison of demand, manufacturing ability and sales in Tamagochi

Source: *Dynamic simulation of the supply chain for a short lifecycle product – Lessons from the Tamagochi case ([13])*

A key factor to avoid this kind of mistakes and make the supply chain able to quickly react to demand changes, and so more resilient, is given by the perfect integration and coordination among three company functions: Marketing, Supply Chain

and Trade (Sales force). The first one takes care of the demand forecasting; the Supply Chain function provides all the constraints related to production (such as capacity, times, etc.) while the Sales department gives in input all the requirements related to the distribution sides.

Another aspect related to short life cycle product is the following: some famous fashion brands, such as Louis-Vuitton, have launched in the past limited-editions of items (for instance in Christmas time or San Valentine holiday) that demonstrated to be so successful to become “must-have” bestsellers; so the companies decided to transform them in continuative products to be sold every year in that particular occasion/period and not just in one season.

From the above considerations it emerges the need to evaluate if the above mentioned operation (the extension of product life-cycle) is worth-while or not in terms of company profitability.

In order to do that, particular KPIs have been defined. As long as it is possible to depurate sales from subjective data (applying for instance correction factors provided by subject matter experts), the KPI is a profit actualised figure, given by the trend on the demand applied to revenues, minus the costs for the item production (considering scaling factors in buying lots of raw materials).

$$Y_i = (\beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \dots + \beta_p X_{ip} + \varepsilon_i) - (C_0 + N_1 C_1 + N_2 C_2 + \dots + N_k C_k) \quad (5)$$

$$i = 1, \dots, n$$

Where:

$$(\beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \dots + \beta_p X_{ip} + \varepsilon_i) \quad (6)$$

is the regression to determine trend factors and

$$(C_0 + N_1 C_1 + N_2 C_2 + \dots + N_k C_k) \quad (7)$$

provides the computation of costs.

In this case it is not merely an application of break-even theories to merchandise and assortment planning, because the determination of beta factors is affected by the necessity of depuration from all the subjective data, question that is still under investigation with subject matter experts.

## 5. 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 paper aims at providing, on one side, a literature review about supply chains vulnerability and resiliency concepts and, on the other one, to provide some insight in regards to particular aspects related to companies producing short life cycle products.

In the near future, the authors will focus their attention on the study and implementation of a System Dynamics model able to describe the behavior of short life cycle products supply chains with the main aim of making them more resilient.

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