A resilient approach to manage a Supply Chain Network

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***Abstract*—Today we depend more and more on logistic networks, which often know nothing, or worse, on which our power of control is almost zero. It is impossible to imagine a life without certain types of products or food, all of that to get us often follow long and complex network and therefore vulnerable. Let see how increase in energy costs has engulfed many small companies. Differently by rising energy costs, there are also changes that are not so easily predictable, so it is essential for the survival of a company to have "redundant" resources, able to operate strategies and proactive behavior. It's important to be flexible and adapt better to the changes that are imposed by external or even internal conditions. More than on flexibility, it is necessary to focus on the concept of Resilience, which requires the ability to remain calm, to address a crisis, but maybe leave it weakened but with the strength, the ability and the confidence to create a tomorrow of own business, adapting to change.**

I. INTRODUCTION

Resilience is derived from Latin verb "re-salio" which connotes the act to back on a capsized boat by the force of the seas, without surrendering despite the difficulties. A more poetic image of resilience is found in the culture of the ancient samurai, their representation of resilience is realized in bamboo image: this is a mysterious plant by incredible flexibility, it can bend without breaking, it suits the circumstances.

When the wind blows, bamboo "murmured", when the wind becomes a storm, the bamboo bends his head and so avoids being broken.

The term, in its practical application, born in materials science: resilience is the ability of a material to regain its original shape after deformation. Technically, Resilience is the ability to absorb energy in the elastic range: "*the modulus of resilience is the strain energy per unit volume stored in the material when the voltage is at the limit of proportionality"*.

The concept of resilience makes it possible to integrate these two contradictory aspects, on the one hand the "vulnerability" on the other side the "capacity".

A psychologist at the University of Chicago, Kobasa Susanna, has identified the three factors that affect the index of resilience of persons, as shown in fig.1.

A resilient person in face of adversity, instead of weakening, increases its strength. A resilient person has a distinctive feature, flexibility, thanks to which it is able to change their mental mechanisms to adapt to the changing situations around. What makes the intern networks most vulnerable is continuous uptake of "lean" logic in the management of the flow, trying to minimize waste, eliminating steps that do not provide value in the process.

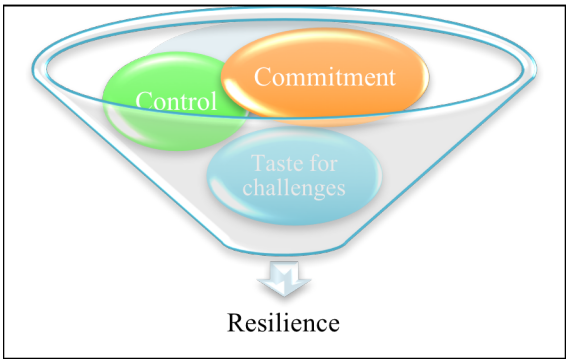

Figure 1. Factors that affect index of resilience persons.

The inter modern networks, therefore, occur more vulnerable to breakage or deformation. A "vaccine" for this situation might be resilience, able to ensure a rapid return to system normality as a result of event and/or unforeseen disturbance defined by literature "disruption".

II. DIFFUSION OF THE RESILIENCE CONCEPT

In Engineering field, Resilience represents the ability of a material to resist impulsive stress. Resilience measures the resistance to break dynamic, with a specific impact test: it's to break with one single blow an audition unified through a machine called Charpy pendulum.

The result of the test is the work absorbed by the test piece, which coincides with the labor expended by the pendulum. Denoting by L the work absorbed by the specimen (measured in Joules), H is the initial height of the bat from which begins the fall (measured in meters), h the height of lift bat after the collision and breakage of the specimen, P the weight of the bat (expressed in Newton), A is the area (cm^2) of the section of the specimen in the longitudinal plane of symmetry of the notch, we calculate equation (1) and (2):

$$L = P \times (H-h) \quad [J] \tag{1}$$

$$K = L/A \qquad [J / cm^2] \tag{2}$$

K is resilience index.

The resilience is also used to find the transition from ductile to fragile behavior and minimum value of temperature fro which material can be used remaining flexible. Ductility defines the ability of a material to

change shape, before breaking; it can be also determined by reduction in section of a specimen.

At the beginning of eighties, the term resilience has spread in psychology field to indicate man's ability to deal with adversity in life, to move forward without surrendering despite the difficulties to get out strengthened and even transformed positively.

The concept of resilience makes it possible to integrate these two contradictory aspects, on the one hand the "vulnerability" on the other side of the "capacity".

Susanna Kobasa of Chicago University has identified three factors that affect the index of resilience people:

1. *Commitment:* evaluate pragmatically difficulties and benefits that the world offers and therefore involve themselves fully in the activities. So there is commitment, it's necessary to have goals to believe.
2. *Control*: do not miss anything, always have the belief that it can control events and always be ready to change themselves.
3. *Taste for a challenge*: to see the changes as positive factors, the difficulties should not be avoided, but to be lived as an opportunity for growth.

A resilient person has a distinctive feature, flexibility, thanks to which he is able to change their mental mechanisms to adapt to the changing around situations. A trivial synonym of psychological resilience is the rehabilitation, i.e. to react and to find a new balance in the face of adversity and trauma. In fact, before spreading in the field of psychology, in the seventies, the concept of resilience has been introduced in the ecological sciences, introducing:

"the ability of a system to absorb a disturbance and reorganize while the change takes place, in such a way as to keep still essentially the same functions, the same structure, identity and feedback".

Four characteristics are to kept under control for a resilient system:

- Latitude: limit threshold by which a system can change while maintaining its ability to recover.
- Insecurity: indicates proximity of the system to the threshold.
- Resistance: the ease with which a system can change.
- Penarchia: a new term that makes clear that resilience of a system to a particular scale depends on the influence of the states of the stairs above and below the system

Ecologist Crowford Holling was to introduce the concept of resilience to ecological sciences. As a result of a catastrophic event, an ecological system can evolve in any way, may also not return to starting conditions but the resilience of the system ensures that following the catastrophe, are maintained predetermine levels of vitality both for functions that for structure of the system. It's necessary to emphasize that the resilience of a system depends on the ability of the actors of the system, since they are able to influence from inside the structure.

A. R-K Strategy

It is a theoretical model which describes the dynamics by which a species grows and states in an ecological system. Lays the foundation for the theories that study the probability of success of a species, studying two variable:

- Biotic potential;
- Bearing capacity of the environment (maximum number of individuals that can be kept in an environment).

r-K selection theory uses the Verhulst equation (3):

$$dN/dt = r\,N\left(1 - N/K\right) \tag{3}$$

in which N is entity number, r is biotic potential, K is bearing capacity, t is time variable.

The Verhulst equation says that the dynamics of a population is a function of the relationship between the r and K variables, that is:

- Species with high reproductive potential rapidly reach the equilibrium situation;
- Species have a low reproductive potential reach slowly equilibrium situation.

Several species implement different development strategies; we can distinguish two extreme cases related to population growth, as shown in figure 2:

- *R strategy:*

Species that are able to take advantage of favorable conditions for transient, rapidly colonizing the environment but fall dramatically at the onset of unfavorable conditions. For these reasons the species r strategy have the upper hand in ecosystems subject to strong seasonal variations.

- *K strategy:*

They are much more demanding species and require stable environmental conditions and in balance. For this reason they have the upper hand in mature ecosystems and the most productive.

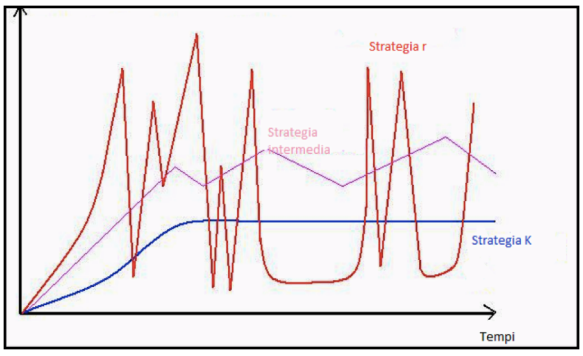

Figure 2. Trends in population growth

III. COMPARISON BETWEEN RESILIENCE CONCEPTS AND LEAN THINKING

Continuous resilience studies have the goal to reducing the vulnerability of corporate networks with regard to materials, information and people flows. The uptake of Lean logic in flows management makes inter-networks most vulnerable. For these reasons, there are conflicting points between resilient and lean companies. Conflicts

arise on efficiency concept for company: while a lean approach tends to reduce waste and uncertainties focusing on stabilization and searching for a stable and controllable equilibrium, resilient company tries to survive by focusing on targeted redundancies. While lean company tends to be flexible with a complete structuring of processes and operations and sourcing strategies, resilient company aims to create a network for supply chain that has targeted redundancy of stocks and capacity.

Trying to optimize supply Chains is a common imperative in recent times, because of we are witnessing a "re-industrialization" in Western Europe, which creates different scenarios for extended Supply Chains.

We can conclude that a supply chain aims to targeted redundancies resulting waste for a lean supply chain, although lean approach often uses redundancy, such as oversized productive resources to manage processes.

Lean Manufacturing tries to minimize waste, clearly identifying process that provides value to the customer to eliminate steps that do not provide value. Steps that add value must belong to a process flow without interruption, a process that is pulled by customer (nothing is produced until there need), so as to reduce stocks. In fact, stocks are not entirely bad, since allowing better insulation from possible external perturbations.

A. The importance of targeted redundancies

Resilience concept is strongly tied to concept of freedom degrees that identify system's ability to overcome the perturbations. Having high freedom degree means having excess resources: the secret of a resilient structure is at being "rich", excess energy that will be useful to the occurrence of difficult situations.

These surpluses cost but improve the vulnerability of the system. However the excess must be optimized, looking for targeted redundancies. It should be noted that resilience and redundancy are not the same thing.

A redundant system duplicates each element; in this way it increases the complexity and managing costs of entire materials/information flow. A resilient system, however, only duplicates essential activities to ensure full continuity of services. Increasing redundancy has only marginal utility: increasing flexibility and radical change in company culture contribute to increase resilience of system. The companies future is full unexpected events; survival of companies is increasingly uncertain if it has no ability to adapt; a solution could be resilience, which according to Crippa, is defined as: *"ability to absorb consequences of significant and sudden changes, restoring a satisfactory condition of equilibrium"*.

Redundancy has, as goal, the possibility of allowing providing services, even in case of unexpected events or faults. Consequently, the company must be characterized by a certain redundancy that allows greater flexibility and adaptation to the circumstances, not only with respect sudden change to conditions due to a disruption, but also with respect to the continuous thrusts of change that penetrate from the outside environment. The redundancy, however, must involve only some resources, those critical resources that allow systems to survive even in the event of a collapse of other structural resources, for this reason we speck of targeted redundancies. They allow the company to have the ability/possibility to reorganize, apparently seems waste but really answers the question of better corporate security in the event of a catastrophic event.

B. Disruption concept

The modern inter networks, more vulnerable to breakage or deformations are present. A "vaccine" for this would be the resilience, which would ensure a rapid return to normal system after the event/unexpected perturbation defined disruption. In figure 3, each disruption is preceded by a warning time, in which the system can foresee the damage and tries to minimize the consequences; after a small period (delay impact), the "destructive" event manifests and destroys the business routine. The company to survive must try to recover, gradually bringing the system after a specific recovering time, to a performance level, equal to or lower than the original, before the impact destructive event.

Sheffi identifies six types of disruptions according to intervention field, as shown in table I. the resilience of the industrial system depends on the flow management, how resources are allocated but also an excess of resources and their re-configurability, as shown in figure 4.

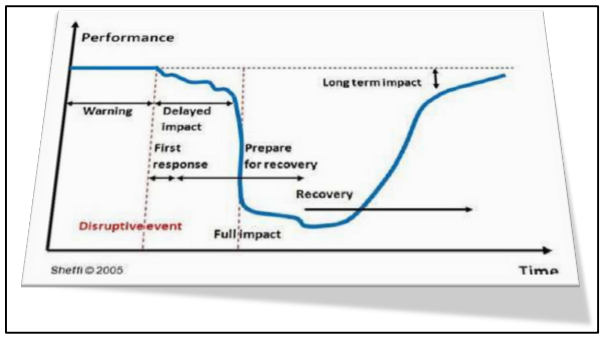

Figure 3. Time profile of a disruptive event according to Sheffi

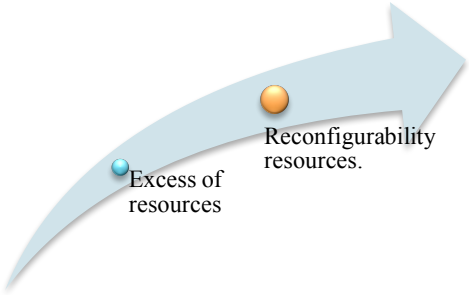

Figure 4. Aspects of allocation resources

TABLE I
DIFFERENT TYPES OF DISRUPTION ACCORDING TO INTERVENTION AREA

INTERVENTION AREA	DISRUPTIONS
MATERIALS FLOW AREA	Attend on the integrity of goods' orders, may be due to theft.
INFORMATION SYSTEMS AREA	Attend on the flow of information associated with that material, blocking communications between the actors responsible for processes of information.
HUMAN RESOURCES AREA	Attend on the availability of personnel and labor specific to processing sector
PROCUREMENT AREA	Attend on the activity of supply, slowing or stopping power to the downstream.

TRANSPORT SYSTEMS AREA	Attend on the transport carriers causing slowdowns and lockout situations.
PRODUCTION FACILITIES AREA	Attend on the operation of the plants and industrial facilities, possibly causing paralysis of the entire process.

TABLE II
POSSIBLE REMEDIES TO THE "DISRUPTIONS" TO THE INTERVENTION AREA

INTERVENTION AREA	REMEDIES
MATERIALS FLOW AREA	Goods Tracking Product traceability (RFId). Product and process control
INFORMATION SYSTEMS AREA	Creating data di back up. Disaster Recovery Plan. Service provider information.
HUMAN RESOURCES AREA	Recruiting suitable staff Substitution plans. Employees Cross training
PROCUREMENT AREA	Policies of inventory management Flexibility of supply contracts
TRANSPORT SYSTEMS AREA	Customer engagement Multiplicity of modes of trasport Multiplicity of distribution centers
PRODUCTION FACILITIES AREA	Variety of sites Agreements with suppliers of equipment and technology

From various types od "disruptions" presented in Table I, Sheffi identifies the specific remedies to each intervention area, as listed in Table II. These corrective actions, increasing the flexibility of the system and reducing its vulnerability, make the whole system more resilient.

C. Resilient for a network

A network defines resilient if it is able to provide and maintain an acceptable level of service compared with failures, always maintaining a normal operation, faults may arise as a result of disruption, which may be or catastrophic events, or attacks of small or large size.

A resilient network maintains acceptable conditions, even in case of:

- ✓ Natural defects in components of the network
- ✓ Failures due to configuration errors
- ✓ Attacks on network hardware
- ✓ Delays
- ✓ Connectivity issues

Events of disturbance for a network may be classified according to their severity in:

- ✓ Slight
- ✓ Moderate
- ✓ Serious

Additionally, the events can be divided into:

- ✓ Predictable: those that can be provided, using information on past events.
- ✓ Unpredictable: ones that we cannot predict when will happen and what will be the consequences.

Unpredictable events are the most dangerous because forcing companies to get in terms of defense, in this way, however, the efficiency of the corporate network is decreased, because resources are excluded and they could be used in any different way.

The complexity of a network contributes positively or negatively to its resilience. Too many redundant connections can create problems, especially as regards the behavior to be maintained in the event of faults. Few connection or network elements can create single points of failure or bottlenecks. For the construction of a resilient network, it's important starting from a holistic view of the problem; otherwise it will not be taken into considerations remedies lasting. The construction of a resilient network, involves the use of a control cycle that describes the conceptual components that can ensure resilience, these cycle is represented in figure 5.

In figure 5, we find the characterizing elements of the construction of a resilient network:

- ✓ Resilience Target: the reference value to be achieved in terms of performance, taking into account the needs of end users and service providers.
- ✓ Defensive measures: are the actions need to take to implement a defensive action, to mitigate the effects of the disruption; the most widely action is redundancy of resources.
- ✓ Challenge analysis: collecting information, for an optimal configuration of the resources needed to implement the challenges against unpredictable events.
- ✓ Resilience estimator: based on the results of two previous points determines whether the objective has been achieved in terms of resilience.
- ✓ Resilience manager and resilience mechanisms: the first is an operator of resilience, while the second element has the responsibility to control the structure.

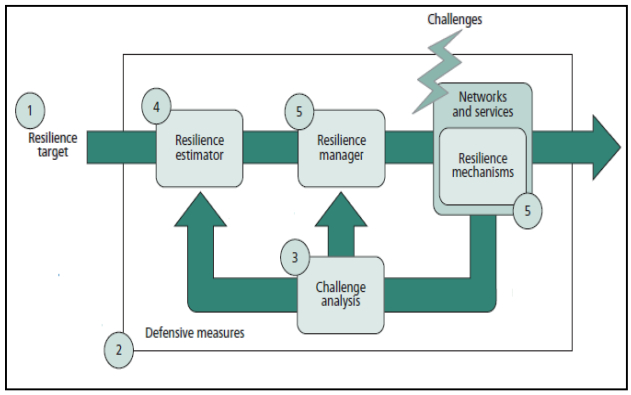

Figure 5. Resilience Cycle Control

Measuring resilience methodology is a tool fro decision support that allows a network (logistics, functional or business) to address the environmental modern dynamics, highly variable. A measure of resilience provides information on the ability of a system to react after a disruption, in order to quickly return to initial levels of performance or at least adequate.

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