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Definition of a framework based on literature review to support strategic decisions to improve Enterprise Resilience

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Abstract: Enterprise resilience is a complex concept that involves different properties and research areas. Based on the literature review, three main properties related to enterprise resilience have been identified: vulnerability, adaptative capacity and recovery ability. On the other hand, an analysis of the current literature approaches to measure and assess enterprise resilience has been described. However, approaches that assess and measure simultaneously the three main properties of enterprise resilience have not been found. To bridge this gap, the paper presents the definition of a conceptual framework to support strategic decisions related to enterprise resilience by defining the main research areas of the identified enterprise resilience properties to provide the basis for further research.

Keywords: Enterprise Resilience, Disruptions, Vulnerability, Adaptative Capacity and Recovery Ability

1. INTRODUCTION

The business and economic environment is changing continuously. Aspects such as shorter products' life-cycles, more power of customers in negotiation processes, increased dependence on supplier capabilities, new technologies, regulatory requirements, rapidly changing of customer preferences, international market and production expansion, accidents, strikes, sabotage, fires, floods have high a direct impact on enterprises performance (Wagner and Neshat, 2010). In order to give an adequate and quick response to these situations, enterprises should be robust, agile, flexible, adaptable and dynamic to adapt as quick as possible to any critical event. This characteristic has been defined as enterprise resilience.

Resilient enterprises are those who examine continuously the dynamism of the environment, questioning their practices, goals and tactics, are committed to its mission, vision and values in order to convey, both internal and externally, values of safety, cohesion and confidence and face crisis environments and disruptive events, articulating high-risk decisions based on the analysis of information coming from the environment, interacting with competitors, customers, ... and managing the change in order to adapt to the new situation.

2. ENTERPRISE RESILIENCE

The concept of resilience was first defined in the ecological field. Holling (1973) defines this term as a system that persists in a state of equilibrium (stability) and how dynamic systems behave when they are stressed and move from this equilibrium.

Dalziell and McManus, (2004) propose using the term resilience to describe the overarching goal of a system to continue to function to the fullest possible extent in the face of stress to achieve its purpose, where resilience is a function of both the vulnerability of the system and its adaptative capacity.

Minolli (2000) states that resilient enterprises are able to absorb changes and ruptures, both internal and externally, without thereby affecting its profitability and even develop a flexibility which, through rapid adaptation processes, get extra benefits, whether pecuniary or intangible, arising from adverse and / or unforeseen circumstances.

Gallopin (2006) describes enterprise resilience as an enterprise adaptative capacity and its ability to cope with, adapt and recover after a disruption. The author also explains how well an enterprise can decrease the level of its vulnerability to expected and unexpected risks, how agile it is in reorganizing itself despite its changing

environment, and how effective it may be in recovering in the least possible time and at the least possible expense.

McManus (2007) states that resilience is a function of an organisation’s situation awareness, identification and management of keystone vulnerabilities and adaptive capacity in a complex, dynamic and interconnected environment. An enterprise that has a high resilience is the one most likely to cope with problems that arise every day and successfully manage all aspects that cause the crisis.

Erol et al., (2010) define enterprise resilience as an enterprise’s capability to decrease the level of its vulnerability to expected and unexpected threats, its ability to change itself and adapt to its changing environment, and its ability to recover in the least possible time in case of a disruptive event.

Sheffi and Rice, (2005) state that building resilience should be a strategic initiative that changes the way an enterprise and that increases its competitiveness. Ballesta (2010) characterizes a resilient enterprise as the one with the ability to anticipate key events related to emerging trends, to constantly adapt to changes and to recover quickly from disasters and crises.

In the different definitions of enterprise resilience, there are common topics addressed to this term. Aspects such as disruption, vulnerability, adaptative capacity and recovery ability are used in the different enterprise resilience definitions. Table 1 shows a summary of the different aspects of enterprise resilience found in the literature review:

Table 1. Aspects included in Enterprise Resilience definitions

	Disruption	Adaptative Capacity	Recovery Ability
Minolli (2000)			
Dalziell y McManus (2004)			
Gallopín (2006)			
McManus (2007)			
Ballesta (2010)			
Erol et al., (2010)			

Based on the previous analysis, the enterprise resilience is function of (i) the enterprise vulnerability; (ii) the adaptative capacity and (iii) the recovery ability as it is shown in Fig. 1.

$$\text{Enterprise Resilience} = f(\text{Vulnerability, Adaptative Capacity and Recovery Ability}).$$

Enterprises need to be as resilient as possible in order to face up to disruptions. Barroso et al., (2008) defined a disruption or its synonymous disruptive event as a foreseeable or unforeseeable event, which affects directly the usual operation and stability of an enterprise.

Barroso et al. (2008) propose a framework to support enterprises in the identification and management of disruptions. To do this, they define that disruption of a specific enterprise is based on four dimensions: (i) intensity, (ii) time-span, (iii) scope and (iv) time-to-disturbance.

Sheffi and Rice (2005) explain that any significant disruptive event has an impact on business performance, whether measured in sales, production level, benefits, customer service or other relevant metrics, and divide a disruptive event into 8 different phases: 1. Preparation; 2. Disruptive event; 3. First response; 4. Initial impact; 5. Time of full impact; 6. Preparation for recovery; 7. Recovery and 8. Long-term impact Disruptive events may cause disruptions in flows of information, materials and/or finance in an enterprise. These disruptions may have a

negative influence on an enterprise's normal operations, thus making it vulnerable and reducing its performance and competitiveness (Barroso et al., 2011).

In the following subsections the three main properties of enterprise resilience are described in more detail.

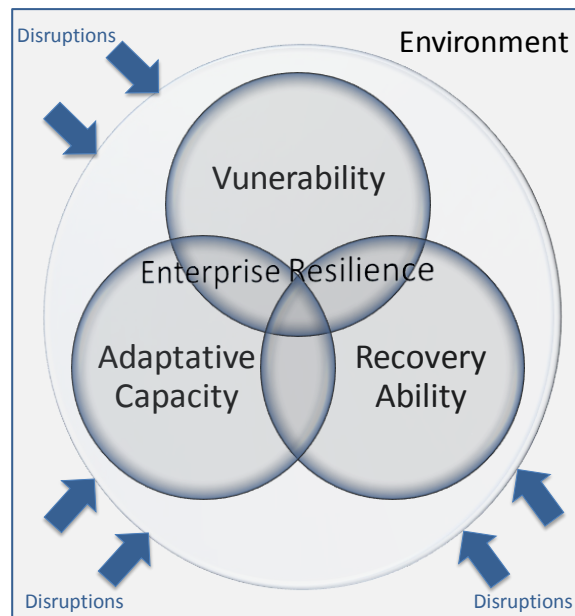


Fig. 1. Main properties of enterprise resilience.

2.1 Enterprise Vulnerability

The vulnerability is an area that has a direct relationship with the disruptions previously explained. Dalziel and (2004) explains that the point at which a disruptive event occurs is when an enterprise is pushed from one state of relative stability or equilibrium into another. The ease with which the enterprise is pushed into this new state is a measure of its vulnerability.

Vulnerability management defines the operational and strategic aspects of enterprise, which have the potential to have significant negative impact in a crisis situation (McManus, 2007). Reducing vulnerability means reducing the likelihood of a disruption and increasing the resilience, the ability to bounce back from a disruption (Sheffi and Rice, 2005).

2.2 Adaptive capacity

The adaptive capacity is a very important factor related to enterprise resilience and it is defined as the degree to which an enterprise is able to cope with the disruptive event (Dalziell y McManus, 2004). Starr et al., (2004) defined it as the ability of an enterprise to alter its strategy, operations, management systems, governance structure and decision support capabilities to withstand disruptions.

McManus (2007) considers adaptive capacity as a measure of the culture and dynamics of an enterprise to take decisions appropriately and in the time required both in the daily activities and in crises and disruptive events.

Dalziell and McManus, (2004) explain that a system can adapt to changes in different ways: (i) application of existing available responses to address the problem. This may include increased utilisation of existing resources and/or functionality; (ii) application of an existing response in a new context to address the problem and (iii) application of novel responses to address the problem.

2.3 Recovery Ability

The last property of the enterprise resilience is the ability to recover from a disruptive situation. In today's highly dynamic environments, an enterprise is never a static entity. Some sectors are more stable than others, however,

an enterprise that remains static in the same position, loses its potential to achieve its purpose. Enterprises should also change in response to changes in environment to maintain its competitive advantages (Dalziell and McManus, 2004).

When an enterprise has resilience capacity, is ready to adapt to a new set of circumstances after a disruption. While when the enterprise only has recovery ability, all the enterprise efforts are focused on returning to its pre-disruption state.

Some authors state that the recovery ability is a subset of the adaptive capacity. However in this work, the adaptive capacity is focused on the short-term (on phases 3, 4 and 5 of a disruption phases defined by Sheffi and Rice, 2005). The main objective of the adaptive capacity of an enterprise is to achieve the best use of the enterprise available factors to suit to immediate changes. On the other hand, the centre of attention of the recovery ability is on the long-term (phases 6, 7 and 8 of a disruption phases defined by Sheffi and Rice, 2005) in order to improve enterprise capacity to facilitate its adaptation to the competitive environment and achieve permanent enterprise development and business continuity.

3. APPROACHES TO MEASURE ENTERPRISE RESILIENCE

To achieve enterprise resilience it is necessary to understand and evaluate the factors that affect enterprise resilience. It is therefore necessary to study enterprise resilience approaches that offer a vision of how resilient an enterprise is from different perspectives to (i) be aware of potential disruptions and (ii) take the appropriate decisions to mitigate the impact of the lack of enterprise resilience.

Due to the fact that the concept of enterprise resilience is a recent term, few approaches that propose ways of measuring and assessing enterprise resilience have been found in the literature. Some of them try to determine measurement methodologies and factors of enterprise resilience although it is widely recognized that the status of such methods is emerging and highly theoretical. Erol et al. (2010) make a literature review of some of the approaches to measure and assess enterprise resilience, shown here.

Paries (2006) and Haines et al. (2008) study the emergent properties of enterprise resilience and explain that it cannot be measured directly as an AS IS condition assessment, but it should be seen as a feature in the evolution of system dynamics. Rose and Liao (2005) describe enterprise resilience with two main characteristics: inherent and adaptive. To measure both characteristics propose a mathematical optimization model. Wreathall (2008) proposes an approach that uses a combination of two modelling techniques: viable system model and soft system modelling. Through this combination, the author aims at developing means to identify key processes, i.e. what to do and how it can be achieved, since enterprise resilience is defined as the result of continuous processes, including planning for resilience, response to unexpected changes when faced with extreme situations and the capacity to adapt with the main objective of recovery.

On the other hand, there are standards such as British Standard BS 25999, which is managing the business continuity of an enterprise when a disruption occurs, whether due to an accident or major disaster or a minor incident in order to help enterprises minimize the risk of disruptions. Its benefits include improving the resilience of an enterprise proactively when faces with an interruption in their ability to achieve key objectives (BSI, 2011).

Sheffi and Rice (2005) and Westrum (2006) propose vulnerability maps to categorize the likelihood of potential threats and the relative enterprise resilience to face up to such disruptions. Dalziell and McManus (2004) propose to define key performance metrics to evaluate resilience as a function of the vulnerability of a system and its adaptive capacity within a desired time frame. Finally, Erol et al. (2010) propose three resilience measurable factors: (i) the recovery time, (ii) the level of recovery and (iii) the level of vulnerability to disruptions, and point out that an enterprise could be resilient to a type of disruption but this does not mean that that enterprise could be resilient to another type of disruption. This leads them to argue that a possible measure of the overall concept of enterprise resilience can be a function of individual resilience of an enterprise to face up to different disruptions.

Table 2. Literature approaches to measure enterprise resilience with regards to its three main properties

	Vulnerability	Adaptative capacity	Recovery ability
Paries (2006)			
Haimes et al. (2008)			
Rose and Liao (2005)			
Wreathall (2008)			
British Standard BS 25999			
Sheffi and Rice (2005)			
Westrum (2006)			
Dalziell and McManus (2004)			
Erol et al. (2010)			

These approaches deal with the measurement and assessment of enterprise resilience taking into account the three main properties of enterprise resilience: vulnerability, adaptative capacity and recovery ability. However, no approach has been found in the literature that assesses and measures these three main properties simultaneously (Table 2). For this reason and in order to bridge this gap, the present paper provides a general framework that includes the three main enterprise resilience properties and its related research areas to be the first attempt for defining the corresponding indicators to measure and assess enterprise resilience.

4. DEFINITION OF THE FRAMEWORK TO SUPPORT DECISION RELATED TO ENTERPRISE RESILIENCE

As aforementioned building resilience should be a strategic initiative, however it is necessary to measure and asses enterprise resilience including operational, tactical and strategic levels of an enterprise to support the strategic decision-making process.

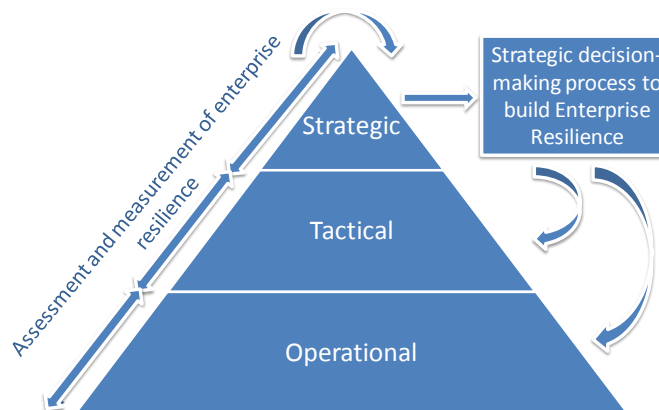


Fig. 2. Strategic decision making process related to enterprise resilience

Lord Kelvin formulated the famous sentence: “When you cannot measure it, you cannot improve it”. For this reason, it is important to measure and assess, in this case enterprise resilience, to be able to manage it properly.

Besides an accurate measurement process, an assessment phase is also required. Therefore, the measurement and assessment process consists of obtaining quantitative information on e products and processes that are being developed, as well as an exploration phase, in which an analysis of how the data influence the actions or plans of the enterprise should be developed.

The Software Engineering Institute (2012) supports the previous idea, explaining that the measurement without further assessment/analysis is meaningless:

- Why measure and assess? Because without data, the only thing obtained is opinions.
- Why analyze/assess? Because the data collected cannot help if it is not understood and used it to shape decisions.

Moreover, four requirements for the measurement and analysis process are identified as it shown in Fig. 3.

Salguero (2001) explains that the indicators to be measured and assessed must have the following characteristics:

- They should be easily identifiable to avoid difficulties in their measurement and assessment.
- Only what is really important should be measured and assessed, that is only what is truly representative for decision making should be measured.

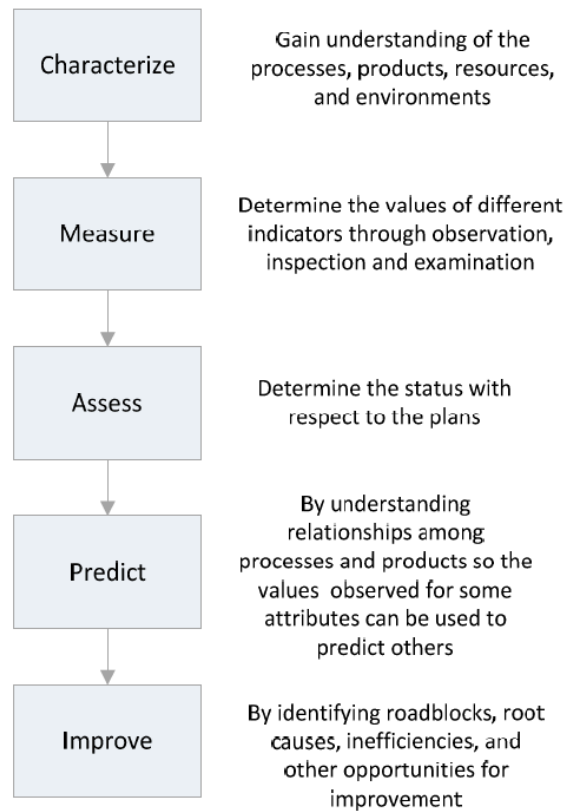


Fig. 3. Steps to be followed in the measurement and analysis of enterprise properties (based on SEI, 2012).

- What to measure and assess and why should be understood very clearly.
- The most important thing is the "package" or "set" of indicators, not a particular one.

Moreover, an indicator should have the following components (Tavera and Castellanos, 2009):

- Objective: The purpose of the results of the measurement of a given indicator.
- Definition: Build the collective meaning of the indicator.
- Design: The indicator should be composed of variable name (what is going to be measured); denominator (the goal to target); and numerator (the current value of the indicator, taking into account the planned target).
- Responsibility: Who leads the process of creation and realization of products or processes on which the indicator is measured.
- Time: The time limit for carrying out the measurement.
- Processing: To carry out the measurement and obtain results in order to support the decision-making process. According to the results obtain, it should be assessed what actions should be taken.
- Evaluation and continuous improvement: To assess whether the decisions were correct and / or need to be corrected or updated.

Once it has been explained the importance of measuring and assessing enterprise properties and showing a few guidelines about how the indicators should be defined, the efforts are focused on providing a first attempt of framework that includes all the enterprise resilience properties and its related research areas.

The main objective of this framework is to be the foundation for further research in order to define the most appropriate and relevant indicators to measure and assess enterprises resilience.

Based on the extensive literature review, three main properties related to enterprise resilience have been found. The concept of enterprise resilience is global and comprises several different research areas. Therefore it is complex to measure how much resilient an enterprise is, if it is ready to face up disruptions and with which time, cost and level of recovery. If an enterprise wishes to measure its enterprise resilience should take as a basis this framework as checklist to ensure that all the research areas have been taken into account:

Table 3. Framework with the main research areas to support the measurement and assessment of enterprise resilience.

Property	Areas of research
Vulnerability	Predictability
	Enterprises should be constantly aware about the external environment to predict any potential disruption that may occur in order to be prevented before the disruption happens.
	Likelihood/Frequency
	It is important to asses the probability of occurrence of a disruption in order to asses how vulnerable an enterprise is and to focus the efforts on the more probable disruptions.
	Preparedness
	Enterprises should evaluate the readiness to face disruptions, assessing if they have the knowledge, means and resources to face different disruptions.
	Coverage
	Another area to be analyzed is importance and number of enterprise components affected by the negative effects of the different disruptions (e.g. human resources, products, processes, ...).
	Criticality
This area is related to the assessment of the impact and potential effects of a disruption affecting an enterprise.	
Adaptative capacity	Degree of tolerance
	Enterprises should take into account the study of the accumulated variation between the current status and the status after a disruption to define which the level of stress that they are able to support.
	Flexibility
	Enterprises should asses how they adapt to the changing requirements of its environment and its stakeholders with minimum time and effort.
	Agility
	The resources and creativity of enterprises to respond instantly to unplanned events should be evaluated. The assessment of the ability to continue operating depends only on enterprise agility to propose solutions immediately and to carry them out.
	Robustness
The maintenance of enterprise performance either when subjected to external, unpredictable perturbations or when there is uncertainty about the values of internal design parameters should be evaluated.	
Recovery Ability	Redundancy
	Enterprises should assess if it is appropriate to keep extra capacity and/or resources in reserve to be used in case of a disruption
	Level of recovery
Enterprises should decide based ion the analysis of the previous research areas to which level they should move to. Sometimes the level of recovery is not exactly the same that the one before the disruption since the time that enterprises are achieving such a level is influenced by the continuous dynamisms of the environment.	
Time to recovery	

Enterprise should define which the recovery time should be in order to be aware of the changes that occur in the environment during its recovery.

Cost to Recovery

Finally, the enterprise should also assess the cost of recovery in order to choose the most appropriate alternative.
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As aforementioned, this framework is the first step to define different methods and indicators to assess how resilient an enterprise is. Aspects and its associated indicators such as the level of exposure, the cascade effect, the suppliers' base, the visibility, etc, will be taken into account to assess the vulnerability property. The adaptive capacity will be analyzed with regard to some factors such as the level of connectivity, the communication channels, the internal and external resources capacity, etc. Finally, in the assessment of the recovery ability, indicators related to strategic management, roles and leadership, recovery priorities will be considered to make up a global framework to assess enterprise resilience.

5. CONCLUSIONS AND FURTHER RESEARCH

The concept of enterprise resilience is very complex as it involves several concepts, aspects and different research areas. Based on the literature review, three main properties of enterprise resilience have been identified: vulnerability, adaptive capacity and recovery ability. However, in order to be able to measure and assess these three properties, it is necessary to define its related research areas. The framework presented in this paper is a first step to define different indicators related to each research area and property to obtain a global overview of the status of an enterprise with regard to its degree of enterprise resilience. Further research is focused on:

- The extension of the framework with other research areas that could be relevant to measure and assess the enterprise resilience.
- The definition of measurable indicators to assess the three main properties of enterprise resilience, taking into account the research areas described in the present framework.
- The study of similar fields such business continuity, risk management... to find synergies with the current research in enterprise resilience.
- The implementation of a piloting case in a real scenario, i.e. the complete version of the framework that will include the definition of all the necessary indicators will be tested in a real enterprise to be enhanced.
- Based on the results obtained with the previous step, mitigation policies, improvement strategies will be defined to improve the capacity of enterprise resilience.

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