Supply Chain Resilience: Definition Of Concept And Its Formative Elements

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ABSTRACT

The objective of this paper is to conceptualize Supply Chain Resilience (SCRes) and identify which supply chain capabilities can support the containment of disruptions and how these capabilities affect SCRes. Through a systematic and structured review of literature, this paper provides insights into the conceptualization and research methodological background of the SCM field. A total of one hundred and thirty four carefully selected refereed journal articles were systematically analyzed leading to the introduction of a novel definition for SCRes, which the authors view as the as "the ability to proactively plan and design the Supply Chain network for anticipating unexpected disruptive (negative) events, respond adaptively to disruptions while maintaining control over structure and function and transcending to a post-event robust state of operations, if possible, more favorable than the one prior to the event, thus gaining competitive advantage". Finally, a critical examination of existing conceptual frameworks for understanding the relationships between the SCRes concept and its identified formative elements, is taking place.

Keywords: Supply Chain Resilience; Supply Chain Management; Supply Chain Disruptions

1 INTRODUCTION

The word resilience has its origins in Latin, where 'resiliō' had the meaning of springing back; recoiling; rebounding (Babylon Online Dictionary, 2011). In modern English the verb 'resile', according to the 11th edition of the Oxford Concise Dictionary (2008), means recoiling to resume a former size. In the world of science, the resilience concept can be initially traced back in engineering, representing the quality of a material of being able to store strain energy and then upon unloading to have this energy recovered, without breaking or being deformed (Gordon, 1978; Avallone, 2007). Simply put, a resilient material is capable of recovering from strain or deformation caused by a compressive stress (American Society for Testing Materials, 2005). For the last forty years resilience has proven to be a highly multidisciplinary concept, finding application in several scientific fields other than engineering such as ecology, social engineering, psychology, economy, and organizational management each presented with proprietary definitions and research perspectives. In this paper we analyzed the research efforts as described in a sample of one hundred and thirty four journal papers sourced from the HEAL link and Scopus academic databases. These papers are the outcome of our screening process, during which we kept in the sample only peer-reviewed publications. Prefaces, editorials, book reviews, interviews and testimonials were excluded from our sample.

Resilience – The ecology perspective

Resilience, for ecological systems is approached under two seemingly similar, but yet quite different perspectives. Pimm (1984) in his work on the complexity and stability of ecosystems introduces resilience as a characteristic of a system's stability and defines it as a measure of how fast a system returns to equilibrium following a perturbation. On the other hand Carpenter et al. (2001) and Gunderson & Holling (2001) provide relatively overlapping definitions of resilience as the magnitude of disturbance that can be tolerated before it moves to a different region of state space controlled by a different set of processes. These two approaches are specifically discriminated by Holling (1996), the pioneer in the introduction of resilience and stability in the research of ecosystems, and Peterson (1998), both attempting a comparison between engineering resilience and ecological

resilience. They both agree, that the two contrasting aspects of stability – the one that focuses on maintaining efficiency of function (engineering resilience) and one that focuses on maintaining existence of function (ecological resilience) are so fundamental that they can become, as Peterson says, alternative discipline paradigms. According to Grimm & Vissel (1997) engineering resilience as defined by Holling (1996) is relatively similar to the stability property of elasticity while the second approach refers to dynamics far from any equilibrium steady state and is defined as the capacity to absorb shocks and still maintain "function" (Brand, 2008). In a recent paper by Walker et al. (2004), a more integrated definition of resilience in ecological systems is provided according to which "resilience is the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks—in other words, stay in the same basin of attraction". Finally, there seems to be a consensus regarding resilience's properties in ecological systems. Carpenter (2001) based on the interpretations by Holling (1973; 1996) states that resilience has the following three properties: (a) the amount of change the system can undergo and retain the same controls on structure and function), (b) the degree to which the system is capable of self-organization and (c) the degree to which the system can build the capacity to learn and adapt. At the same page, Folke et al. (2002), state that resilience, for social-ecological systems, is related to (a) the magnitude of shock that the system can absorb and remain within a given state, (b) the degree to which the system is capable of self-organization, and (c) the degree to which the system can build capacity for learning and adaptation. The main consideration stemming from both approaches is the concept of adaptive capacity (Smit & Wandel, 2006), a significant component of resilience that reflects the learning aspect of system behavior in response to disturbance (Gunderson 2000). Adoptive capacity implies a dynamic interplay between sustaining and developing with change (Folke, 2006), thus unlike sustainability the outcome of resiliency can be desirable or undesirable and finding and achieving a favorable new system state can be a very risky and cumbersome process (Scheffer, 2001). The same applies to supply chains, according to Pettit (2010), where it may be beneficial for a supply chain not to return to its original shape following a disruption, but rather to learn from the disturbance and adapt into a new configuration.

Resilience – The Psychology perspective

Resilience in psychology was first introduced by Garmezy (1973) as a result of his over 15 years studies on antecedents of developmental psychopathology, dealing with children of mentally ill parents with elevated risk of developing disorders. Despite that, his research proved that many children of schizophrenic parents did not suffer psychological illness as a result of growing up with them (Coutu, 2002). He concluded that a certain quality of resilience against the stresses of a hostile environment was responsible for his research outcome. This observation led the term childhood resilience in the forefront of theoretical and empirical research of developmental psychopathology for many years (Masten, 1990). Since then research in psychology regarding resilience, according to Luthar et al. (2000), has expanded to include multiple adverse conditions such as chronic illness (Kralik et al., 2006), catastrophic negative life experiences (Masten & Obradovic, 2008), urban poverty (Anthony, 2008) and community violence (Copeland-Linder, 2010). Reich (2006) provides a psychological perspective on natural and human-created disasters by introducing three core principles, he calls '3Cs', of human resilience and briefly discusses the way they can be implemented to support future disaster planning and responding. These principles are a) control, by making possible for people to restore control of their lives e.g. set their own goals, make their own decisions, and guide the events of their own lives b) coherence, i.e. reducing the uncertainty the disaster imposes by enhancing meaning, direction, and understanding and c) connectedness, i.e. providing the necessary informational and emotional support by reestablishing stable bonds with other people. What is important to pinpoint here, is that in contrast to the image of resilience as a 'super material' (Porac, 2002), in psychology, resilience has a more developmental nature, i.e. the entity's continuing ability to use internal and external resources to develop and successfully resolve stressing issues. Thus the developmental perspective captures a component of resilience that is often neglected in its application in organization theory—resilience is the capacity to rebound from adversity strengthened and more resourceful (Sutcliffe & Vogus, 2003).

2 ORGANIZATIONAL RESILIENCE

In the world of enterprises the concept of organizational resilience has emerged as a relatively new tradition in organizational theory that incorporates insights from both coping and contingency theories (Gitteli, 2008). According to Sutcliffe & Vogus (2003), organizational resilience often has been used to refer to a) the ability of an

organization to absorb strain and preserve (or improve) functioning despite the presence of adversity or to b) the ability of an organization to recover or bounce back from untoward events. One has to note here the significant overlaps with the concept of organizational agility which Sharifi and Zhang (1999) define as the ability to cope with unexpected challenges, to survive unprecedented threats of business environment, and to take advantage of changes as opportunities. Literature study proves the existence of two discrete approaches on organizational resilience. Some scholars see organizational resilience as simply an ability to rebound from unexpected, stressful, adverse situations and to pick up where they left off, while others visualize organizational resilience beyond restoration to include the development of new capabilities and an expanded ability to keep pace with and even create new opportunities (Lengnick-Hall et al., 2011; Ponis & Koronis, 2012), as presented in Table I.

Table I: Definitions of Organizational Resilience

	Definitions of Organizational Resilience
Wildavsky (1988)	Resilience is the dynamic capacity of organizational adaptability that grows and develops over time
Horne & Orre (1998)	Resilience is a fundamental quality of individuals, groups, organisations, and systems as a whole to respond productively to significant change that disrupts the expected pattern of events without engaging in an extended period of regressive behavior
Mallak (1998)	Resilience is the ability of an individual or organisation to expeditiously design and implement positive adaptive behaviors matched to the immediate situation, while enduring minimal stress'
Coutu (2002)	The ability of an organization to face reality with staunchness, make meaning of hardship and improvise solutions from thin air.
Sutcliffe & Vogus (2003) & Vogus & Sutcliffe (2007)	Organizational resilience is the maintenance of positive adjustment under challenging conditions such that the organization emerges from those conditions strengthened and more resourceful.
Hamel & Valikangas (2003)	Organizational Resilience refers to a capacity for continuous reconstruction. It requires innovation with respect to those organizational values, processes, and behaviors that systematically favor perpetuation over innovation.
Fiksel (2006)	The capacity of an enterprise to survive, adapt, and grow in the face of turbulent change
Lengnick-Hall et al. (2011)	The firm's ability to effectively absorb, develop situation-specific responses to, and ultimately engage in transformative activities to capitalize on disruptive surprises that potentially threaten organization survival

All the above definitions share a common perspective on organizational resilience which exceeds the recovery boundary and implies a certain level of flexibility, improvisation and ability to adapt to both positive and negative influences of the environment (Ponomarov & Holcomb, 2009). Consequently, as Legnick-Hall et al. (2011) state, organizational resilience is tied to dynamic competition, and a firm's ability to absorb complexity and emerge from a challenging situation stronger and with a greater repertoire of actions to draw from than were available before the disruptive event. Finally, this developmental perspective of resilience, as Sutcliffe & Vogus (2003) argue, implies the presence of latent resources that can be activated, combined, and recombined in new situations as challenges arise. Activating resilience is thoroughly discussed by Powley (2009) in that it supports organizations to begin the healing process after trauma or major disaster, restore important and critical organizational relationships, and reestablish and strengthen organizational practices.

3 SUPPLY CHAIN RESILIENCE

The 21st century's unstable and highly competitive business environment is calling for a fundamental reassessment of the way contemporary supply chains are doing business (Tatsiopoulos et al., 2004; Spanos et al., 2007). More like world class competing athletes that are constantly asked to run faster, jump higher and throw further, modern supply chains are continuously stressed by both competitors and customers to produce more customized and complex products in low costs, high quality and with a global customer reach (Ponis & Spanos, 2009). This harsh reality coupled with the emergence of natural and man imposed hazards, in a volatile environment of financial instability and on-going crisis, have put concepts, somehow neglected in the past, such as supply chain resilience and vulnerability, in the forefront of supply chain research in the last ten years. According to Bakshi &

Kleindorfer (2009) the primary reason for the increased interest in disruption management and consequently, supply chain resilience and vulnerability issues is the awareness, promoted by recent research, regarding the magnitude of losses (direct and indirect) resulting from supply chain disruptions.

In that sense, Supply Chain Resilience (SCRes) is currently considered a critical component of Supply Chain Risk Management (SCRM) (Ponomarov & Holcomb), 2009), and a relatively new and yet underexplored research area of management as a whole. Still as Christopher & Peck (2004) state, SCRes is a scientific field of research in its ascendancy. To support that statement, Falasca et al. (2008) argue that the topic of resilience emerged a few years ago in the supply chain management literature and has recently become more widely recognized while Craighead et al. (2007) identify a surge in academic and practitioner publications in a series of disruption related themes, one of them being supply chain resilience. The significance of SCRes in the context of contemporary global supply chains is further validated by the latest Gartner's Supply Chain Top 25 report (2011), in which authors identify resilience as being the one of the four major themes for 2011, stating that supply chain leaders finally took some very clear lessons, with the most important being the need for supply chain resilience, i.e. the ability to deliver predictable results, despite the volatility that is now here to stay.

Supply chain resilience, like organisational resilience, is a multi-dimensional and multidisciplinary phenomenon (Datta et al., 2007a; Ponomarov & Holcomb, 2009). Several definitions do exist that lend significant characteristics from resilience definitions from disciplines reviewed in the previous section. In the early days, SCRes was discussed by researchers either as part of supply chain vulnerability studies (Svensson 2000; 2002) or as a component of supply chain risk management (Juttner et al., 2003). Juttner & Maklan (2011) make a quite elaborated conceptualization of supply chain resilience and identify and explore empirically its relationship with the related concepts of supply chain vulnerability (SCV) and supply chain risk management (SCRM).

A first concise definition of SCRes can be found in Christopher & Peck (2004) who, following a research on building the resilient supply chain in Cranfield University define resilience as the ability of a system to return to its original state or move to a new, more desirable state after being disturbed. At about the same time, following a three years research project on organizational resilience in MIT, Sheffi (2005) makes an interesting transition stating that SCRes no longer implies the ability to manage risk but also the opportunity of a supply chain to be better positioned than the competition and even gain advantage from disruptions. From that point onward, several researchers have provided the academic community with definitions of SCRes, as shown in Table II.

Table II: Definitions of Supply Chain Resilience

	Definitions of Supply Chain Resilience
Fiksel, (2003;2006), Pettit et al. (2010)	SCRes is the capacity for complex industrial systems to survive, adapt, and grow in the face of turbulent change.
Gaonkar & Viswanadham (2007)	SCRes is the ability to maintain, resume, and restore operations after a disruption.
Datta et al. (2007)	SCRes is not just the ability to recover from mishaps, but is a proactive, structured and integrated exploration of capabilities within the supply chain to cope with unforeseen events.
Falasca et al. (2008)	SCRes is the ability of a supply chain system to reduce the probabilities of a disruption, to reduce the consequences of those disruptions once they occur, and to reduce the time to recover normal performance.
Ponomarov & Holcomb (2009)	SCRes is the adaptive capability of the supply chain to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations at the desired level of connectedness and control over structure and function.
Barroso et al. (2011)	SCRes is ability to react to the negative effects caused by disturbances that occur at a given moment in order to maintain the supply chain's objectives.

4 DISCUSSION

Applying a critical evaluation on the fundamental definitions of Christopher & Peck (2004; 2005) and Sheffi (2005) and the most recent ones presented in Table II, we note that they have significant overlaps since most

of them agree in the adoptive and developmental nature of resilience which should guide supply chains not only to recover from a disruptive event or crisis but moreover to find stability in a better state than before. In this paper we will postulate in agreement with Juttner & Maklan (2011) and Barosso et al. (2011) who state that the definition of Ponomarov & Holcomb (2009), is highly multidisciplinary and considers several key elements when a supply chain disruption occurs, namely, response and recovery to the same or a better state, and retention of the same control over structure and function.

Despite the high degree of agreement in what SCRes is by definition, current literature is presented with significant disparity on the core dimensions or formative elements Juttner & Maklan (2011), that each approach deems crucial for the establishment of the 'resilient supply chain' of the new crisis-prone era. To that end, Christopher & Peck (2005) provide an insight of the five principles that guide resilience, these being a) having a good understanding of the supply chain network and applying reengineering practices, b) applying a collaborative supplier base strategy based on information sharing, c) creating and maintaining agile supply chain networks capable of responding rapidly to changing conditions and e) introducing a supply chain risk management culture. Characteristics such as agility, availability, efficiency, flexibility, redundancy, velocity, and visibility, in this initial approach were treated as secondary factors (Petitt et al., 2010). Sheffi (2005) identifies three ways of developing resilience a) increasing redundancy i.e. keeping excess inventory, maintain low capacity utilization, multi-sourcing etc., b) building flexibility by for example applying concurrent instead of sequential processes and c) changing the corporate culture. At the same lines, Rice and Caniato (2003) suggest a mixture of flexibility and redundancy, depending on different cost and service characteristics as well as on specific business and industry factors, to improve SCRes and security. Kleindorfer & Saad (2005) propose ten principles which should guide the implementation of successful disruption risk management. The ninth principle suggests strong emphasis to flexibility and mobility of supply chain resources as an efficient way of increasing its resiliency. In what seems to be a verbal, not in essence, contradiction Tang (2006) proposes the application of robust supply chain strategies as he claims that this will lead to more resilient organizational structures. Drawn from a whole different perspective and heavily influenced of the work by Craighead et al. (2007), comes the approach of Falasca et al. (2008) who identify three network centric determinants of SCRes, a) supply chain density, b) supply chain complexity and c) supply chain node criticality. In the same lines, (Hong and Choi, 2002) provide an empirical study based on three companies of the automotive industry presenting the significance of supply chain structure in the operation and sustainability of a supply chain. Finally, Juttner & Maklan (2011) identify four formative elements of resilience as the most frequently mentioned and those that capture the conceptual essence of all suggestions in current SCRes literature, these being a) flexibility, b) velocity, c) visibility and d) collaboration.

In the last five years research related to SCRes seems to be evolving into more materialized efforts in the form of proposed models and frameworks. Datta et al., (2007) propose an agent based computational framework for studying a complex multi-product, multi-country supply chain subject to demand variability, production, and distribution capacity constraints with the aim of improving its resilience. His findings are empirically validated in a paper tissue manufacturing supply chain. Pettit et al., (2010) identify fourteen capability and seven vulnerability factors and propose a conceptual SCRes framework capable of pinpointing weaknesses in supply chain networks and provide managerial guidance for setting priorities to create a strategy for improving SCRes. Their framework is validated with focus groups and interviews in an apparel and beauty care products retailer with a complex global supply chain. Falasca et al (2008), in an attempt to incorporate a quantitative and measurable definition of resilience, propose a simulation-based framework that incorporates concepts of resilience into the process of supply chain design. Ponomarov & Holcomb (2009) propose a conceptual framework of the relationship between logistic capabilities and supply chain resilience. Their conceptual model is based on an exhaustive literature research and empirical validation remains an item of the future research agenda of the authors. Finally, Juttner & Maklan (2011), in what seems to be the most integrated approach to SCRes so far, after defining SCRes and conceptualising the links between SCRes, SCV and SCRM they present an empirical exploration of these linkages in a longitudinal case study of three supply chains from different industrial sectors.

5 CONCLUSIONS

In this paper, based on the extensive literature review presented above we define SCRes as "the ability to proactively plan and design the Supply Chain network for anticipating unexpected disruptive (negative) events,

respond adaptively to disruptions while maintaining control over structure and function and transcending to a post-event robust state of operations, if possible, more favorable than the one prior to the event, thus gaining competitive advantage". Furthermore, based on our review the most grounded antecedents of SCRes are agility, flexibility, velocity, visibility, availability, redundancy, mobilization of resources, collaboration and supply chain structure knowledge. In developing our framework, we attempt a grouping of the aforementioned SCRes formative elements into four discrete first level structural elements, based on grounded theory as identified by our literature review. In doing so, we view flexibility (Swafford et al., 2006) and velocity (Christopher & Peck, 2004) as antecedents of agility which is the first structural element of our framework. The third element is redundancy, which we differentiate from flexibility and subsequently agility in alignment with Sheffi (2005). The third element of our framework is collaboration as manifested by information sharing, collaborative work and joint decision making (Lee, 2004; Singh and Power, 2009). In contradiction with Christopher & Peck (2004), we don't consider visibility as an element of agility but rather as one of collaboration. Finally, the knowledge of supply chain network physical and informational structure (Hong & Choi, 2002) is the fourth first level element of the proposed SCRes framework.

It is the aim of the authors, to empirically test the validity of the introduced concepts and framework as presented in this paper. This process has started already and it includes the determination of SCRes drivers and their interrelationships, the elaboration of the research hypotheses and finally the design of a structured questionnaire which will act as the main instrument for collecting survey data from more than two hundred Greek SMEs, within 2012. The timeline of this future research project is critical since it is in our intentions not only to explore the validity of our conceptual constructs, but furthermore to explore their relevance in the context of the global financial crisis.

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