QUALITY PAPER

An integrated approach to organizational resilience: a quality perspective

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Abstract

Purpose – The main components of resiliency, including resilience capacities, resilience activities and resilience measures, are identified, extracted and redefined by designing their ontologies. The integrated model is developed by adapting the PDCA (plan, do, check and act) model to resilience management and implementing the developed concepts in the model.

Design/methodology/approach – This study uses systems theory to define the main concepts discussed in the literature on resilience. This study then uses systems engineering theory and a resource-based view of the firm to develop an integrated framework to demonstrate how a resilient firm operates.

Findings – The revised terminologies and the integrated model address the current theoretical issues in the literature, and they also provide a reference model for practical implementation of resilience management at the firm level. Also, the integrated model addresses the role of innovation in resilience management.

Originality/value – The study examines the concept of resilience form a quality perspective and also examines how resilience and innovation are related.

Keywords Firm resilience, Resilience measure, Resilience capability, Resilience capacity, Innovation

Paper type Research paper

1. Introduction

Firms often use control systems to detect internal and external changes in order to take advantage of market opportunities, avoid business threats, decrease their organizational weaknesses and enhance their organizational strengths (Simons, 1990). These control systems may not be sufficient to effectively respond to external shocks, such as disruptions, that can severely affect a company's performance in a very short time. Thus, organizations need to develop capabilities to be responsive to disruptions.

There are different types of disruptions: natural disruptions, such as hurricanes, economic/financial disruptions, such as the Great Recession in the US between 2007 and 2009, sociopolitical disruptions, such as Gulf War, operational disruptions, such as the grid blackout in the northeastern US in 2004, technological disruptions that dramatically change competition rules in a market (Madni and Jackson, 2009), supply chain disruptions disturbing the flow of goods or services (Ambulkar *et al.*, 2015) and human interventions, such as cyber attacks that seriously harm information technology infrastructures. Disruptions can negatively affect the performance of a firm in different ways: natural disasters can damage physical resources, a scandal, such as the Facebook data scandal in 2018 (Frenkel *et al.*, 2018), can damage reputations, a supply chain failure (lack of materials, parts or

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components) can interrupt production lines, emerging disruptive technologies can lead to losing market share and a war or political crisis can affect the overall direction of an economy. To enable companies to be responsive to disruptions, the concept of resilience has been studied by researchers in the management area. As shown in Figure 1 published in Web of Science, there was remarkable growth between 2000 and 2017 in the number of articles regarding resilience in management and business journals. In addition, a number of national and international standards are published in the organizational resilience domain. For instance, ISO 28002 specifies requirements for a resilience management system in a supply chain to enable an organization to develop and implement policies, objectives and programs, taking into account legal, regulatory and other requirements to which the organization subscribes (International Organization for Standardization, 2011).

There are several issues involved in the topic of resilience as it is discussed in the literature. First, some concepts in resilience are used with slightly different meanings. For example, the concept of "adaptability" is used to refer to the capability of learning (Ali *et al.*, 2017; Pech and Oakley, 2005; Ponomarov and Holcomb, 2009) and also to the knowledge learned from coping with a disruption (Linkov *et al.*, 2013). Second, some frameworks or conceptual models are developed without proper attention to the meaning of the concepts and their real roles in resilience management. Third, some of the concepts or key terms in organizational resilience have multiple dimensions, so those concepts or key terms need to be more accurately defined to cover all related aspects or features. These issues are more deeply discussed in Section 3.

This study aims to address these issues in organizational resilience through redefining the main concepts of resilience and proposing an integrated model. In doing so, all literature review papers published between 2000 and 2018 are considered in this study. The definitions, frameworks and models related to the main concepts of resilience at the firm level are extracted and scrutinized. After analysis of the extracted definitions and recognition of the main concepts in the literature, this study redefines the main concepts and provides an integrated model of resilience management. These are the goals of this study: 1) from a systems engineering perspective, redefine the main concepts and adjust their meanings in the context of resilience; 2) add *innovation* as a fourth main function in the resilience management

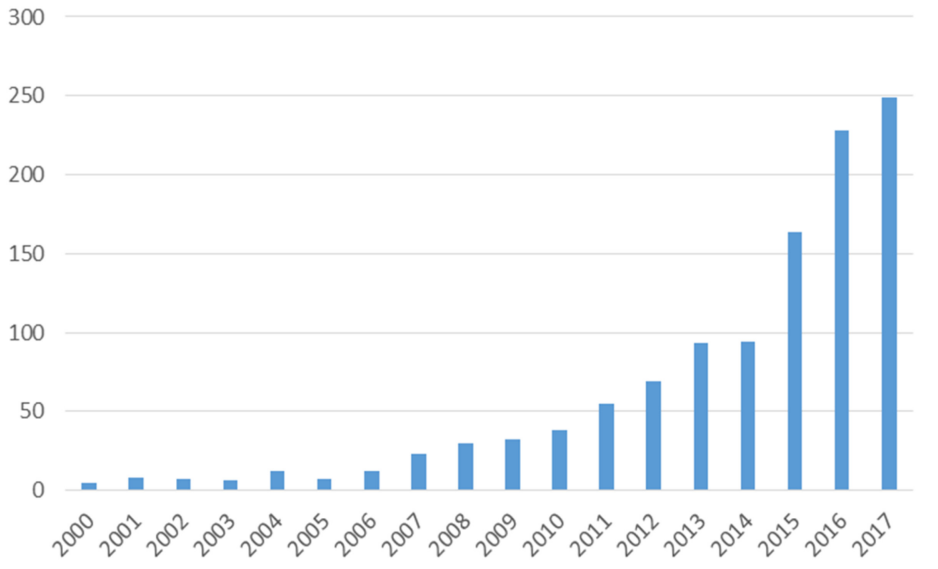

Figure 1.
Number of papers on resilience published between 2000 and 2017

cycle; 3) differentiate between the concepts of *capability* and *capacity* to allow more accurate definitions of the main concepts and 4) expand the definition of resilience based upon resilience capacities, resilience activities and resilience measures.

2. The pattern of disruption

The reference point for this study's discussion on organizational resilience is provided by the general pattern of disruption. Figure 2 shows the impact on firm performance during the three stages of predisruption preparation, the disruption event and postdisruption (Sheffi and Rice, 2005). There may be subtle differences in the number of stages and the terminologies applied in similar models, but the main idea of the pattern is solid in the literature (Sheffi and Rice, 2005). A disruptive event may happen in a few minutes, or a few hours, or even in a few days, but it has the specific pattern shown in Figure 2. In order to manage the impact of a disruption on the performance of a firm, it is required to consider the three stages in time (Sheffi and Rice, 2005). The first stage is before a disruption, when a firm has an opportunity to predict possible disruptions and prepare for them. The second stage is during a disruption. The second stage starts a little after a disruption when a firm faces the initial impacts of the disruption; this second stage continues with the direct consequences of the disruption and finishes when the disruption is completed and has had its full impact on firm performance. For example, in the case of an earthquake, the second stage starts with shaking of the Earth and the destruction of physical infrastructures, continues with direct consequences, such as fires and explosions, and ends when the fires have been extinguished. The third stage starts *after* the time when a disruption is completed, and a firm prepares to recover from the long-term impacts of the disruption. For example, in the case of an earthquake, the third stage is when damaged physical infrastructures would be reconstructed. Overall, the three time phases of before, during and after a disruption are considered in the context of resilience.

In order to cope with disruptions at each stage of the pattern shown in Figure 2, a resilient firm must enhance a set of specific capabilities, including resources, infrastructures, processes, leadership, culture and collaboration. The enhanced capabilities are called *resilience capacities* in the modified terminology offered in this study. To achieve the resilience capacities, a resilient firm should accomplish a set of activities that are called *resilience activities* in this study. The resilience capacities considered in this study are a *predictive* capacity before a disruption, *absorptive* and *adaptive* capacities during a disruption, and a *restorative* capacity after a disruption. Resilience performance is evaluated by a set of measures called *resilience measures* that are developed based on the resilience capacities. Resilience capacities, resilience activities and resilience measures are discussed in Section 6.

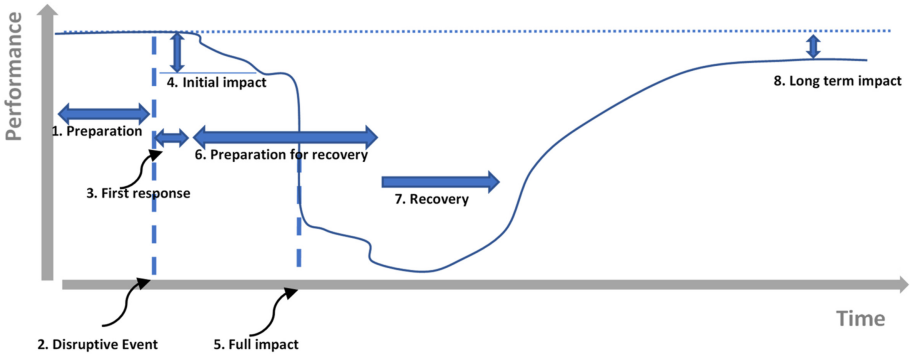

Figure 2.
A disruption pattern (Sheffi and Rice, 2005)

3. Background

Resilience has been studied in many disciplines, such as ecology (Cumming, 2011; Pickett *et al.*, 2013), engineering (Francis and Bekera, 2014; Hosseini *et al.*, 2016), sociology (Hall and Lamont, 2013), psychology (Yates and Masten, 2012), economics (Plummer and Armitage, 2007) and organizational analysis (Akgün and Keskin, 2014). Researchers have been studying how an entity (i.e. human, structure, community) or a firm should react against an environmental shock and survive in turbulent conditions. A firm often exists in a supply chain; the firm receives inputs from suppliers and delivers outputs to customers in a supply chain. Therefore, resilience studies at the supply chain level and at the firm level are applicable to each other. In this study, resilience studies at the supply chain level are reviewed and utilized to discuss organizational resilience at the firm level.

Although many literature reviews of resilience at the firm level and supply chain level have been published, the concepts and models in the literature need clear terminology (Hohenstein *et al.*, 2015). There is still no well-accepted definition of resilience to overcome inconsistencies and to theoretically develop the concept of resilience through antecedents, attributes, capabilities, elements and enhancers (Hohenstein *et al.*, 2015). Some key terms such as agility, flexibility and robustness are used in the literature with broad meaning without precise definitions, and some key terms are intermingled with some others (Hohenstein *et al.*, 2015). This study aims to reconcile these issues in the resilience literature.

The first issue mentioned above is that some concepts in organizational resilience are used in different ways. For example, adaptability refers to knowledge learned from an event (Linkov *et al.*, 2013) and also to learning capability (Ali *et al.*, 2017; Pech and Oakley, 2005; Ponomarov and Holcomb, 2009), while the majority of the literature defines adaptability as the ability of a firm to adjust or reconfigure itself in response to unforeseen changes (Bakshi and Kleindorfer, 2009; Wieland and Wallenburg, 2012). Adaptability is related to learning, but adaptability and learning are two different concepts. This means that learning could be regarded as an antecedent of adaptability and needs to be conceptualized accordingly.

The second issue mentioned above is related to the development of frameworks or conceptual models. Elements such as performance measures, resilience activities and organizational capabilities are organized in a model or framework without enough attention to their roles in resilience management. For example, Soni *et al.* (2014) offer a measurement model that contains agility, collaboration, information sharing, sustainability, risk and revenue sharing, trust, visibility, risk management culture, adaptive capability and supply chain structure. In this model, agility and adaptive capacity are abstract measures applicable to performance measurement; information sharing is a resilience activity, as is risk and revenue sharing; trust and supply chain structure are capabilities; trust and collaboration are abstract results possible from resilience activities. In another example, Kamalahmadi and Parast (2016) offered a two-level framework extracted from an extensive literature review. They presented supply chain reengineering, including flexibility, redundancy, collaboration (including trust and information sharing), agility (including visibility and velocity) and culture (including leadership and innovation). In their framework, supply chain reengineering pertains to resilience activities, collaboration and culture represent organizational capabilities, and agility is a measure to evaluate performance. Additionally, many frameworks or models presented in the literature (Fiksel *et al.*, 2015; Kamalahmadi and Parast, 2016; Sheffi and Rice, 2005; Soni *et al.*, 2014) do not link their elements with the stages of a disruption (before, during and after) shown in Figure 2. Consequently, the models or frameworks do not represent all aspects of resilience in the different stages.

The third issue in the literature is that some concepts/terms have multiple aspects, and they should be more accurately defined and modeled to cover all related aspects or features. For example, agility has a broad meaning and multiple aspects, so it should be conceptually designed with more factors, such as visibility and velocity, and then accurately defined. The

use of general terms such as agility without accurate design and definition can lead to misunderstanding and misuse of them in a framework or model.

There are a few other issues in the literature reviews, but most of the issues originate from either a lack of accuracy in the definition and applications of the terms or from a lack of discrimination between their meanings. The issues are summarized in Table 1.

3.1 A quality approach to organizational resilience

A quality perspective of organizational resilience provides a useful framework to examine how organizations can develop capabilities to become more resilient. Introducing quality management programs that are in line with principles of quality systems such as ISO-9000 can assist organizations to be more effective in operating in unpredictable business environments (Øgland, 2008). Implementing a robust quality assurance system is related to organizational resilience capability (Das and Lashkari, 2015). To improve organizational resilience, firms should work with quality suppliers and partners to improve their risk readiness and resilience. In the context of project-driven supply chain management, it is discussed that practices such as information sharing can assist managers to mitigate supply chain disruptions and improve resilience, thereby ensuring that the goals of quality, time and efficiency are achieved (Gaudenzi and Qazi, 2021).

The relationship between quality management and organizational resilience can be examined from the perspective of organizational learning. Quality management is always looking for ways to improve organizational performance; improvements are primarily achieved by creating new knowledge that can be used by the organization to improve organizational processes (Linderman *et al.*, 2004). Li *et al.* (2011) discuss the relationship between organizational learning mechanisms (explorative learning and exploitative learning) and product quality. In addition, both innovation and resilience are directly impacted by the ability of a firm to innovate. Sabahi and Parast (2020) show that organizations with a higher level of innovativeness are more resilient to disruptions. In another study, Parast (2020) shows that organizations with a higher level of research and development (R&D) investment are more resilient to supply chain disruptions. In this study, we use a learning perspective of quality management utilizing a plan–do-check–act (PDCA) model to examine organizational capabilities that improve firm resilience.

4. Methodology

In this research, we use literature reviews on resilience to deductively extract the current knowledge and terminologies of resilience at both the firm level and the supply chain level. In order to resolve the existing issues in the literature on resilience that were discussed in Section 3, we use a systems engineering approach (Kossiakoff *et al.*, 2011; Böhme *et al.*, 2014). Systems engineering provides a holistic view to examine a complex phenomenon by breaking it down to its elements, recognizing the relationships between the elements, determining the necessary requirements to achieve the functionality of the phenomenon, modeling the interactions between the elements and finally designing measures to evaluate the performance of the phenomenon. A systems engineering approach to understanding supply chain management has been used in prior studies (Zhao *et al.*, 2019). Following the systems engineering approach, we took these steps: 1) identification of system needs, 2) development of "system requirements" based on "needs" and 3) development of a model to show how a resilient system operates (Chapman *et al.*, 2018, p. 2). Thus, by considering a resilient firm as a system, the methodology is based upon these stages: 1) identify issues in the literature reviews on resilience, 2) determine the features required to redefine the concept of a resilient firm and 3) develop an integrated functional model covering all main components of the concept of resilience and other elements required for resilience management. The integrated model is presented in Section 7. To capture the definition of resilience in the

Issue	Example/Explanation	Sample references
Inaccurate meaning	"Adapt" is defined as learning capability	Ali *et al.* (2017), Linkov *et al.* (2013), Pech and Oakley (2005), Ponomarov and Holcomb (2009)
Contradictory meanings	Activities and measures are not appropriately matched; for example, anticipation of change and preparedness for change are considered activities for robustness	Ali *et al.* (2017)
Poor definition	"Capacity" is poorly defined as "availability of assets to enable sustained production levels." This definition is not consistent with the meaning of capacity that is "the maximum amount of something" or "the ability or power to do something"	Pettit *et al.* (2010)
	Descriptions of absorptive, adaptive and restorative capacities are not accurate	Proag (2014)
Lack of discrimination	Lack of discrimination between absorptive capacity and adaptive capacity; they are completely different in terms of time, types of required resilience activities and consequently their resilience measures	Ali *et al.* (2017)
	Security, responsiveness and resilience are considered independent concepts	Melnyk *et al.* (2010)
Misapplication	Despite an accurate definition of robustness, preparedness mechanisms are applied for robustness	Wieland and Wallenburg (2013)
Oversimplification	Some complex concepts/terms have oversimplified definitions that do not cover all related aspects	Soni *et al.* (2014), Kamalahmadi and Parast (2016), Fiksel *et al.* (2015)
Inhomogeneous elements	Some elements represent the performance of a resilient firm, some are the activities required to achieve resilience, some are abstract measures applicable to assess performance and some are general organizational capabilities	
No linkage with the pattern of disruption	There is no linkage between the stages of the disruption pattern and the models or frameworks. Consequently, the models or the frameworks do not represent all the aspects of resilience in the different stages of a disruption	
Partial definition of resilience	Only agility and flexibility are considered main mitigating strategies against supply chain disruptions	Braunscheidel and Suresh (2009)
	Only the effects of agility and robustness are studied on business performance and customer values. In the given study, robustness literally represents the concept of flexibility	Wieland and Wallenburg (2012)
	The performance measures of resilience are only responsiveness and flexibility	Sheffi and Rice (2005)

Table 1.
Common issues in defining resilience

literature in the form of ontology, three sub-steps are taken in the second stage above: 1) identify the main components and relationships in resilience definitions, 2) produce precise, unambiguous definitions of resilience and its components and 3) identify the terms that refer to required concepts introducing resilience and its components (Uschold and Gruninger, 1996).

As shown in Figure 3, in the first step, 140 literature review papers and some of their cited papers are reviewed in this study. The literature review papers were found by the Google Scholar engine among peer-reviewed journal papers published between 2000 and 2018. The keywords applied in the search were "resilience," "literature," "review," "framework," "model," "supply chain" and "firm." Since some papers cited in the literature review papers support our discussion, they were considered in this research as well. The definitions, frameworks and models related to the main concepts of resilience at the firm level were extracted and scrutinized in an ad hoc process. First, some recently published literature review papers (Datta, 2017; He *et al.*, 2018; Hosseini *et al.*, 2016; Kamalahmadi and Parast, 2016; Kochan and Nowicki, 2018; Pires Ribeiro and Barbosa-Povoa, 2018) were selected as the starting point to more efficiently study the latest discourse of resilience definitions. The definitions of resilience in the literature were extracted, and the current issues in the terminology and theory of resilience were recognized.

In the second step, resilience redefinition, the definition of resilience was built based upon its ontology. Also, the main components of resilience were recognized and defined based on their ontologies developed during the search of the literature reviews. The recognized issues in resilience terminology were reviewed to avoid similar issues in developing the ontologies and definitions.

In the third step, an integrated resilience model was developed based on the resilience management reference model introduced in Section 7. The model contains the main components of a resilient firm: resilience capacities, resilience activities and resilience

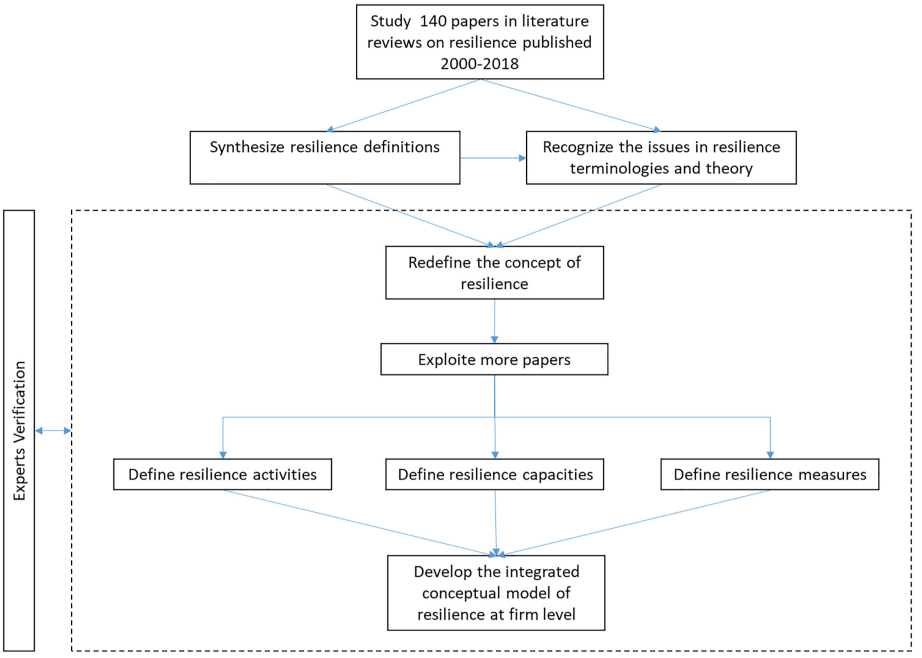

Figure 3.
Methodological process

measures. The model shows how other required elements such as organizational capabilities and the innovation process interact with other components in resilience management. Finally, all definitions and the functional model were verified by experts. Some minor modifications were made to the definitions and the model based on the experts' feedback.

5. Analysis of resilience definitions

Resilience definitions were extracted from published literature review papers and analyzed from three perspectives: 1) the definition of resilience, 2) activities leading to resilience and 3) measures applied in resilience measurement.

The definitions of resilience offered by a set of authors are analyzed in Appendix. The main goal of the analysis is to recognize general elements of the definitions describing resilience. To do so, the analyzed elements are organized in Appendix and illustrated in the form of an ontology shown in Figure 4. Briefly, the concept of resilience refers to this general statement: "*an entity performs a set of activities to enhance its abilities to cause a set of results against changes.*" Therefore, there are five main elements in the ontology of resilience:

(1) *Entity*: The entity is what is supposed to be resilient against disruptions. The majority of the definitions directly refer to an organization or a firm, but some refer to organizational systems and a few use general terms such as a system.

(2) *Activities*: Activities are general actions suggested by the authors to show how an entity should enhance its abilities. Activities either refer to general actions (such as designing, implementing, retaining, anticipating, preventing, mitigating, repairing, replacing and patching) or more specific actions (such as reducing vulnerabilities, improving awareness and innovating that should affect some part of the entity (such as values, behaviors and processes).

(3) *Ability* is one of the general terms (including capacity, quality, action, capability, property and characteristics) used in the definitions to represent which aspect of the entity should be empowered to respond to disruptions.

(4) *Respond* refers to the expected responses of a firm to changes that affect the performance of the entity. The terms for responding in the definitions include survive, withstand, avoid, reconstitute, absorb, adapt, restore, return and recover.

(5) *Changes* refer to environmental alterations that affect the entity. Disruptions, disturbances, events, damages and perturbations in the environment are among terms representing changes used in the definitions.

These are some issues in the resilience definitions in the literature:

(1) *Incomplete definitions*: Most of the definitions are incomplete; they do not cover all main aspects of resilience, such as "*activity*" or "*result*" as shown in Appendix. For example,

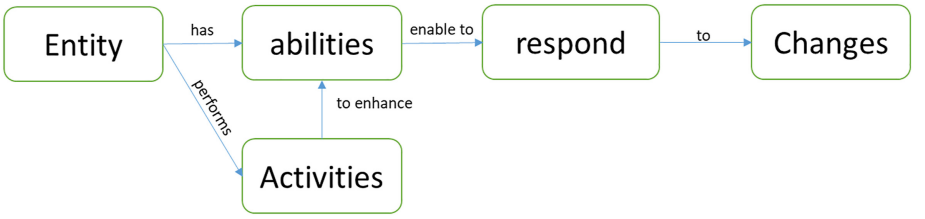

Figure 4.
The ontology of resilience in the current literature

McDonald, (2017) has not addressed the entity and the activities in his definition. The elements missed in the definitions are distinguished by "N/A" in the related cells.

(2) *Confusion about the nature of resilience*: the definitions emphasize different subjects as the core concept of resilience. Some authors refer resilience to different types of outcomes, such as ability (Horne, 1997; Sheffi and Rice, 2005), capability (Mallak, 1998; Reinmoeller and Van Baardwijk, 2005), capacity (Fiksel, 2003; Hamel and Välikangas, 2003) and emergent properties (Burnard and Bhamra, 2011) that each of which is characterized by some attributes such as adaptive and absorptive.

(3) *Disagreement about the activities*: There is disagreement regarding "activities." Authors refer to diverse functionalities such as innovation (Hamel and Välikangas, 2003), increasing awareness (Burnard and Bhamra, 2011) and reducing vulnerabilities (Burnard and Bhamra, 2011). In addition, some authors address general activities that need to be more specific or described to have a precise definition. For example, developing situation (Lengnick-Hall *et al.*, 2011), transformative activities (Lengnick-Hall *et al.*, 2011) and combination/composition of subsystems (Horne, 1997) are used in the definitions, but they need to be interpreted and clarified.

(4) *Disagreement about the abilities:* Although many of the definitions emphasize the concept of *ability*, there is still some disagreement about the abilities required in order to be resilient. Capacity, capability, quality and property are the other terms used to describe the concept of ability. These general terms do not describe what resilience means and what attributes a firm should have.

(5) *Not sensitive to time and different stages*: As shown in Figure 2, a disruption happens in a specific duration of time and contains four stages. Resilience has different characteristics in each stage, and consequently, a resilient firm should respond differently in each stage. This study's review suggests that none of the definitions address *time* as an important aspect of resilience, and none of the definitions clarify the stages and the activities required at each stage.

(6) *Lack of attention to the types of changes:* The definitions only refer to three aspects of changes: 1) they are environmental (He *et al.*, 2018; McDonald, 2017); 2) they disturb (Ates and Bititci, 2011; Burnard and Bhamra, 2011), destabilize (Alberts, 2011, p. 218), or damage (Alberts, 2011, p. 218) and 3) they are unexpected (Woods and Cook, 2017) or surprising (Lengnick-Hall *et al.*, 2011). In addition to these specifications, the changes can be categorized as technological, natural, sociopolitical, economic-financial and operational, as described in the introduction. This categorization shows how the changes are inherently different. The activities required to respond to different changes might be different according to the nature of the change. In the next section, these issues are addressed by redefining the concept of resilience.

6. Redefining resilience

6.1 Differentiating between capability and capacity

Resilience is defined in the Oxford Dictionary as follows: 1) "the *capacity* to recover quickly from difficulties; toughness" and 2) "the *ability* of a substance or object to spring back into shape; elasticity." *Capacity* and *ability* are the two main concepts of resilience, but *capability* is a better term for ability in management terminologies because it is widely used in management literature in terms such as dynamic capability (Teece, 2009) and organizational capability (Bhamra *et al.*, 2011). Thus, we adopt *capability* and build the concept of resilience based upon *capability* and *capacity*.

The meaning of *capacity* in the Oxford Dictionary is as follows: 1) the maximum *amount* that something can contain or 2) the *amount* that something can produce. The meaning of *capability* is "the power or ability to do something." The essential element in the meaning of capacity refers to an "*amount*" of something, while the essential element in the meaning of capability refers to the power or ability of "*doing*" something. Therefore, when something has capability, it means it can do something, and when something has capacity, it means the amount of what it produces or contains. In this context, it can be concluded that capacity describes the maximum amount of a capability. For example, an electrical engine has a capability to produce power, and its capacity is 1,000 kilowatts. Another example is a manufacturing company that has the capability to produce shoes, and its capacity is to produce 1,000,000 shoes per year. Therefore, a firm has some capabilities, and its capabilities have capacities. This relation is reflected in the modified ontology in Figure 5.

Capability has had extensive applications in management literature, particularly in the resource-based view where organizations build their competitive advantage based on their resources (Prahalad and Hamel, 2003; Wernerfelt, 1984). Resources are combined to create capabilities. Therefore, capabilities are organizational abilities utilized to assemble, assimilate and use resources (Bharadwaj, 2000). Organizational capabilities required for resilience are discussed more deeply in Section 7.

6.2 Ontology of resilience

Given the abovementioned discussions, the ontology of resilience should be modified as follows:

(1) *Modification 1*: *Ability* is replaced with *capability,* because *capability* has been discussed extensively in the management literature, so there is less confusion about its meaning.

(2) *Modification 2:* "*Resources*" is added to the ontology. Resources and capabilities are complementary, but resources are not well emphasized in the definitions.

(3) *Modification 3:* "*Resilience capacity*" is added to the ontology. *Capacities* refer to extra abilities developed based on enhancing *resources* and *capabilities* that are particularly provided to make a firm resilient against disruptions.

(4) *Modification 4: Activities* is replaced with "*resilience activities*" to specifically address those activities performed to achieve *resilience capabilities* through increasing *resources* and enhancing *capabilities*. Resilience activities will be discussed in detail in Section 9.

In addition to the above modifications, *time* is one of the issues in previous studies that needs to be addressed. Thus, here is the modification making the resilience definition sensitive to *time*:

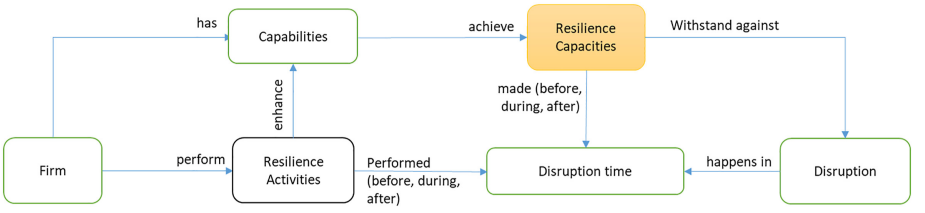

Figure 5.
Modified ontology of resilience at the firm level

(5) *Modification 5: Time* is considered and added to the ontology because resilience is a concept sensitive to disruption time, and a resilient firm should perform *resilience activities* to achieve *resilience capacities* proportionally before, during and after the *time* of *disruption*.

Also, here are two other semantic modifications made to improve the definition of resilience and align it to the context of this paper:

(6) *Modification 6:* E*ntity* is renamed to *firm* to be aligned more accurately to the scope of this paper.

(7) *Modification 7:* C*hanges* is retitled to *disruption* to address more specifically an *environmental event* that *surprisingly disturbs* the performance of a firm.

According to the modified ontology of resilience shown in Figure 5, the definition of resilience at the firm level should convey all the components of the modified ontology. Therefore, using the modified ontology in Figure 5, a resilient firm can be defined as follows:

A resilient firm has resilience capacities that are achieved by enhancing the firm's capabilities through performing resilience activities before, during and after disruptions.

In order to achieve a more comprehensive definition of resilience, it is necessary to conceptually expand the definition's three main components: resilience capacities, resilience activities and resilience measures. These are terms with broad meanings in the context of resilience.

7. Organizational capabilities

Six main organizational capabilities discussed in the literature on resilience are leadership, business processes, resources, culture, collaboration and infrastructures. The six capabilities are enhanced through resilience activities to achieve the resilience capacities discussed in Section 8.

Leadership positively impacts resilience by changing the behavior of subordinate managers and employees through building their confidence and social support, strengthening their risk management skills, and most importantly, facilitating cognitive, emotional and behavioral adaptation (Harland *et al.*, 2005). The main characteristics of the leaders in a resilient firm are to be flexible, adaptable and innovative in dynamic and complex environments (Danielson, 2011).

Organizational *culture* has a positive influence on resilience (Mandal, 2017) and facilitates remaining flexible and adaptable during changes in an operating environment (McManus *et al.*, 2008). Ideally, organizational culture should be adaptive (McManus *et al.*, 2008) and flexible (Sheffi, 2005) through providing employees with a set of principles to use to make appropriate decisions in a timely manner when the formal mechanisms of an organization work too slowly in a disruption (Sheffi, 2005).

Strengthening *business processes*, especially through implementing statistical and information technology capabilities, positively affects predictive, adaptive and restorative capacities (Sincorá *et al.*, 2018). Some scholars have started rectifying business process architectures (Zahoransky *et al.*, 2014), and business process frameworks (Antunes and Mourão, 2011) to resilience. A few researchers have commenced a new approach called risk-aware business process management in which they implement quantitative methods, such as simulation or operations research models, to determine the risks of disruptions, analyze their impacts and finally decide resilience activities, such as resource allocations, against possible disruptions (Jakoubi *et al.*, 2009; Tjoa, 2011; Tjoa *et al.*, 2008).

Adopted from Marsh (1997), *infrastructures* are physical or virtual systems and assets whose failure or damage would have a critical impact on the operations and business

performance of a firm. Infrastructures at the firm level such as the manufacturing system, the transportation system, the power management system and information technology are examples of infrastructures essential for firms to withstand and rapidly recover from disruptions (Francis and Bekera, 2014). Security and safety systems and standards are essential foundations for achieving resilient infrastructures (Kriaa *et al.*, 2015).

Collaboration has been known as one of the most influential factors in supply chain performance (Kache and Seuring, 2014), risk mitigation (Kache and Seuring, 2014) and as a resilience strategy (Carvalho *et al.*, 2012a, b). Collaboration through communication, knowledge and information sharing, and joint planning in a supply chain network increases resilience among all partners (Whipple and Russell, 2007). Visibility, velocity and flexibility resulting from collaboration are the main mechanisms used to increase resilience at firms collaborating at a supply chain level (Scholten and Schilder, 2015).

Many studies provide empirical evidence of how the availability of *resources* results in resilience at different levels (Nelson *et al.*, 2007). Redundant resources allow firms to absorb the initial shocks of disruptions and to more quickly recover from the long-term impacts of disruptions (Rice and Shaeffi, 2005). In contrast, limited resources render firms, particularly small companies, vulnerable to abrupt changes (Bhamra *et al.*, 2011).

8. Resilience capacities

"Resilience capacities" are the core component of the resilience definition proposed here. A firm is resilient if and only if it has the necessary resilience capacities. Resilience capacities are predictive capacity, absorptive capacity, adaptive capacity and restorative capacity (Ali *et al.*, 2017; Francis and Bekera, 2014; Vugrin *et al.*, 2011). Each of the resilience capacities is intended for one of the *before*, *during* or *after* stages of a disruption. Before a disruption, a resilient firm should have *predictive capacity* to be prepared and ready to minimize the negative consequences of a disruption. During a disruption, a resilient firm should have two capacities: *absorptive capacity* and *adaptive capacity*. Absorptive capacity is required to absorb the initial shocks of a disruption so that the firm stays in operational condition. Adaptive capacity is necessary to handle the full impact of a disruption. After a disruption, a resilient firm should have the capacity called *restorative capacity* to recover from the long-term impact of the disruption. For each of these four resilience capacities, the following sections discuss the concept and design the ontology.

8.1 Predictive capacity

In general, predictive capacity is the degree to which a system can predict disruptions and the related vulnerabilities to plan required resilience activities. Vulnerability has been defined as the degree to which a system, or part of it, may react adversely during the occurrence of a hazardous event (Proag, 2014). Vulnerability has a direct relationship with disruptions when disruptions push a firm to unstable conditions (Sanchis and Poler, 2013). This concept of vulnerability implies a measure of risk associated with disruptions (Proag, 2014). Reducing the likelihood of predicted disruptions and gaining the ability to bounce back from their negative consequences to stable conditions leads to a reduction in vulnerability (Sheffi and Rice, 2005). There are different sources of vulnerability such as demand, process, control and environmental risks (Erol *et al.*, 2010). Risk assessment and vulnerability analysis involves the evaluation of possible risks and their consequences (Haimes, 2015; Madni and Jackson, 2009). Proactively anticipating disruptive events is required to avoid the consequences of disruptions (Francis and Bekera, 2014). Therefore, a firm has *predictive capacity* when the firm *predicts* possible disruptions and their probabilities, *recognizes* the severity of the firm's

vulnerable resources and capabilities affected by the predicted disruptions and *plans* resilience activities in order to minimize vulnerabilities. The ontology of predictive capacity is shown in Figure 6.

8.2 Absorptive capacity

Absorptive capacity is the degree to which a system can absorb the impacts of system perturbations and minimize the consequences with *little effort* (Vugrin *et al.*, 2011). Absorptive capacity is the proportion of the original system functionality (performance) retained immediately after a disruption (Francis and Bekera, 2014). The absorptive capacity is an endogenous feature of a system (Vugrin *et al.*, 2011). Absorptive capacity resilience enhancement features include system robustness and system redundancy (Vugrin *et al.*, 2011). System robustness decreases the impact of a disruption through the strength of individual connections in the system. Applying levees that prevent hurricane storm surges from damaging facilities is an example of system robustness. System redundancy decreases the impact of a disruption through providing operational alternatives, such as purchasing materials from multiple, geographically dispersed suppliers (Vugrin *et al.*, 2011). Therefore, a firm has *absorptive capacity* when it has redundant internal resources to compensate for any possible shortage and when it has strengthened the capabilities to keep them functionally robust with little effort immediately after the time a disruption starts. The ontology of absorptive capacity is shown in Figure 7.

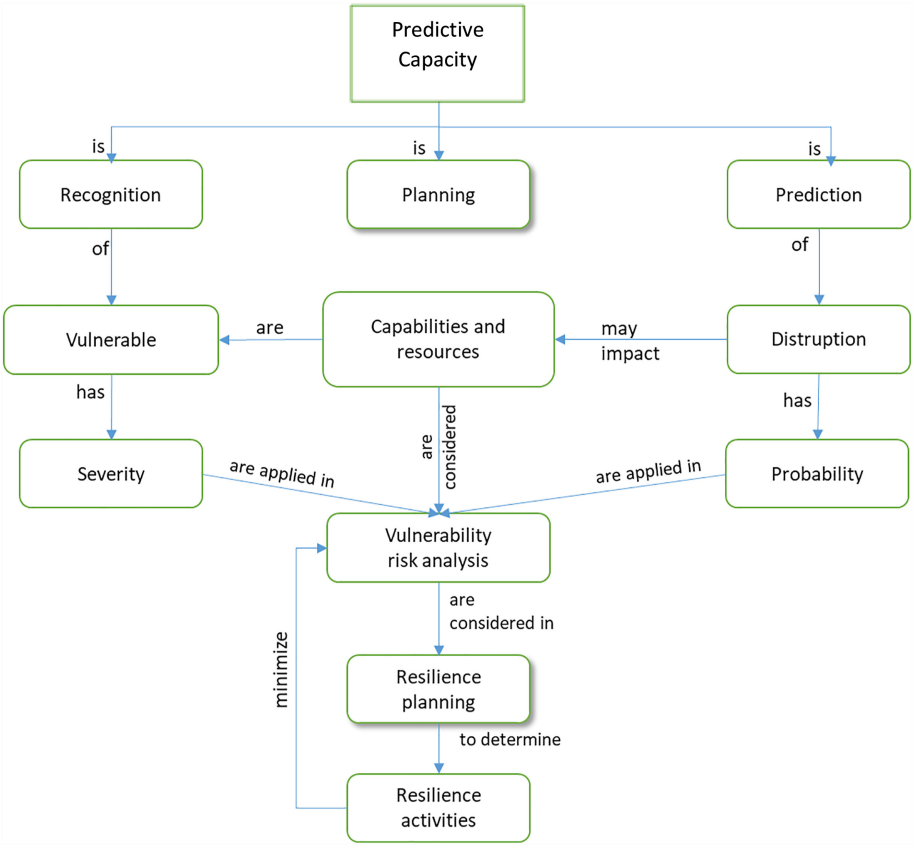

Figure 6.
Ontology of predictive capacity

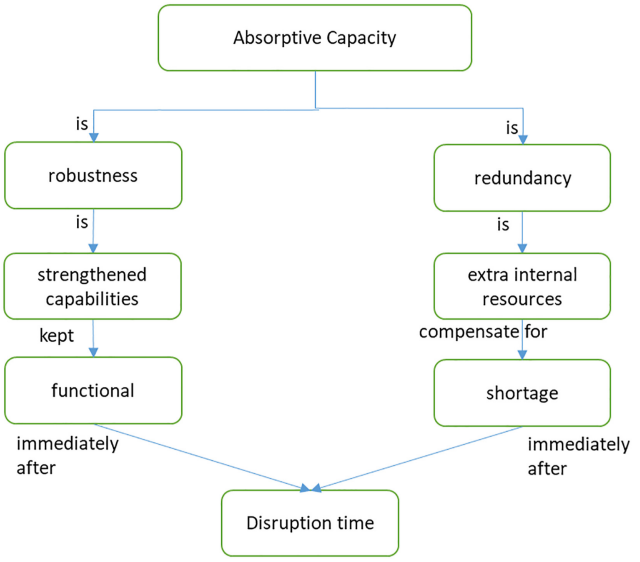

Figure 7.
Ontology of absorptive capacity

8.3 Adaptive capacity

Adaptive capacity is the ability to rapidly respond to unforeseeable changes by reconfiguration (Bakshi and Kleindorfer, 2009; Wieland and Wallenburg, 2012), adaptation and transformation (Parsons *et al.*, 2016) and actions that result from ingenuity or extra effort over time (Vugrin *et al.*, 2011). Adaptive capacity is distinguished from absorptive capacity in that adaptive systems change in response to adverse impacts, especially if absorptive capacity has been exceeded (Francis and Bekera, 2014). Adaptive firms can substitute inputs, use alternate technologies or replace one system component or input with another. The changes can radically alter the structure of a system to restore its performance (Vugrin *et al.*, 2011). Using emergency generators during outage is a good example of how a firm adapts to a disruptive event (Francis and Bekera, 2014). Therefore, a firm has adaptive capacity when it is able to adjust or substitute its components inputs or technologies through innovation or investment based on internal resources in order to alter its structure/configuration to restore normal performance. This provides an important insight into the linkage between adaptive capacity and innovation to deliver resilience. Section 9 has a discussion on the role of innovation in resilience management. The ontology of adaptive capacity is shown in Figure 8.

8.4 Restorative capacity

The restorative capacity of a resilient system is often characterized by the rapidity of its return to normal performance (Francis and Bekera, 2014) and the ability to be repaired (Vugrin *et al.*, 2011). Restoration capacity is equivalently considered to be time and cost required to recover a system after disruption (Ouyang *et al.*, 2012).

There are a few distinctive differences between adaptive capacity and restorative capacity. Whereas adaptive capacity reflects the ability of a system to be changed endogenously, restorative capacity reflects the ability to be repaired in most cases by using external resources and in some cases by internal resources (Vugrin *et al.*, 2011). Another differentiation between adaptive capacity and restorative capacity is that restorative capacity may affect a system's ability to be permanently changed (an investment decision)

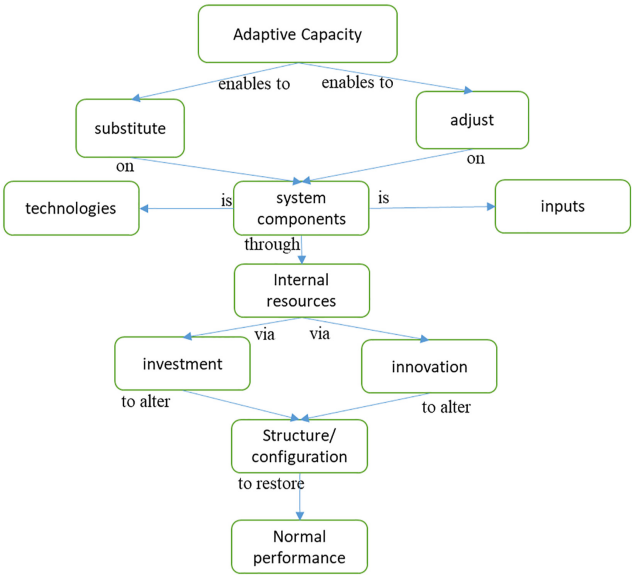

Figure 8.
Ontology of adaptive capacity

while adaptive capacity is primarily concerned with features that are temporary (Vugrin *et al.*, 2011). Therefore, a firm has restorative capacity when it has the required time and cost based on external resources to repair damages and to return to normal performance after a disruption. The ontology of restorative capacity is shown in Figure 9.

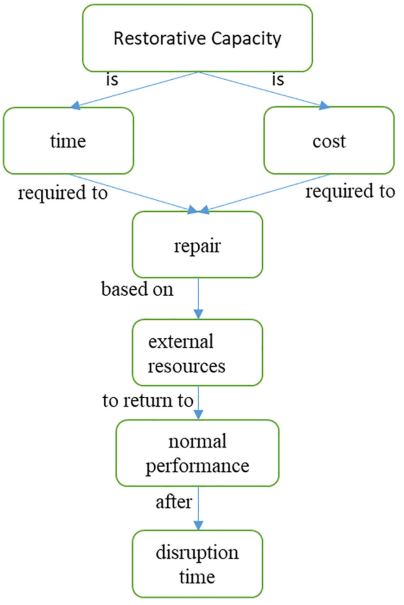

Figure 9.
Ontology of restorative capacity

9. Resilience activities

Resilience activities are actions exclusively required to enhance the firm's capabilities to achieve resilience capacities. Resilience activities are categorized as reactive or proactive activities (Hollnagel, 2011). A reactive action is accomplished when a firm faces an environmental change, while proactive actions are based on forecasting and preempting (Lengnick-Hall and Beck, 2005). Proactive activities are mitigation tactics taken in advance of a disruption, while reactive activities are contingency tactics taken only when a disruption occurs (Tomlin, 2006). Therefore, many activities should be planned and accomplished *before* disruptions to build up predictive, absorptive and adaptive capacities. Most activities applied to build restorative capacity are reactive actions. Required resilience activities are separately identified for each of the resilience capacities; however, firms need to combine resilience activities to appropriately provide a resilience plan to manage the consequences of a disruption (Tomlin, 2006).

9.1 Predictive activities

There have been many instances of companies that failed because of a lack of quick comprehension and rapid response to disruptions. Training front-line employees is one of the requirements to quickly take action against a disruption (Sheffi and Rice, 2005). Preparedness involves predicting disruptions by monitoring (Ivanov *et al.*, 2014) and sensing and interpreting them (Datta, 2017) through early-warning strategies (Saenz and Revilla, 2014) and continuity planning (Pettit *et al.*, 2010). The other requirements to be prepared against disruptions are recognizing potential vulnerabilities and planning to minimize the risks of vulnerabilities (Datta, 2017; Pettit *et al.*, 2010). Leading companies provide training to employees, suppliers and customers about security and supply network risks to raise awareness and reinforce the importance of supply chain resilience (Blackhurst *et al.*, 2005).

9.2 Absorptive activities

Responsiveness is the ability to respond quickly in terms of volume, mix or location (Melnyk *et al.*, 2010). Examples of absorptive activities that allow firms to respond quickly are monitoring systems that create linkage with critical suppliers and customers, excess capacity and control systems that realize when and where a disruption affects a firm's capabilities or resources (Melnyk *et al.*, 2010; Sheffi and Rice, 2005).

Robustness and *redundancy* are mentioned as two main attributes of absorptive capacity (Vugrin *et al.*, 2011). Robustness is defined as the ability of a system to maintain its functionality despite disruptions (Stonebraker *et al.*, 2009). Robust activities configure a network and complexity (Craighead *et al.*, 2007), critical locations (Craighead *et al.*, 2007) and resource buffers (Madni and Jackson, 2009) to withstand a disruption without reconfiguring a system (Madni and Jackson, 2009). Redundancy activities entail many different activities, including modifying inventory levels (Carvalho *et al.*, 2011; Knemeyer *et al.*, 2009; Rice and Caniato, 2003) and maintaining excess maintenance capacity (Rice and Caniato, 2003), excess production capacity (Sheffi and Rice, 2005), excess transportation capacity (Stecke and Kumar 2009) and excess storage facilities (Ratick *et al.*, 2008). Redundant activities facilitate achieving robustness, so robustness is considered a performance measure of absorptivity, and activities to provide redundancy are considered absorptive activities.

Companies typically undertake a series of *security* initiatives designed in advance (Rice and Caniato, 2003) to protect their products or services against contamination, cyber attacks and other unsafe inputs (Melnyk *et al.*, 2010). Secure responses can be classified into three groups: physical security, information security and freight security (Rice and Caniato, 2003). Resilience activities that enhance security include implementing controls/sensors for critical assets and services, dedicating cyber resources to defend against attacks, enhancing the

redundancy of critical physical infrastructure and providing redundancy of data physically or logically separated from the network (Linkov *et al.*, 2013).

9.3 Adaptive activities

Adaptive capacity is the ability to rapidly respond to unforeseeable change by reconfiguration (Bakshi and Kleindorfer, 2009; Wieland and Wallenburg, 2012), adaptation and transformation (Parsons *et al.*, 2016), and actions that result from ingenuity or extra effort over time (Vugrin *et al.*, 2011). Adaptability is achieved through three main groups of activities: flexibility, agility and collaboration.

Flexibility is principally based on substitutability, in which one system component or input is replaced with another (Vugrin *et al.*, 2011). Examples of ways to be flexible are having multiple sources in different locations (Rice and Caniato, 2003), facilitating coordination processes (Manuj and Mentzer, 2008), having back-up suppliers (Tang, 2006), shifting demand across products (Tang, 2006; Veverka, 1999), having flexible contracts (Rice and Caniato, 2003), using modular product design (Hopkins, 2005), and having flexible transportation systems, flexible production facilities, flexible capacity and flexible labor arrangements (Kamalahmadi and Parast, 2016). The cornerstones of flexibility are flexibility in strategy, organization, finance, information systems and manufacturing (Sushil, 2001). Many scholars have discussed the advantages of flexibility versus redundancy (Sheffi and Rice, 2005) and some believe that it is still an ongoing discussion (Kamalahmadi and Parast, 2016).

Agility stresses those activities that enable a firm to improve the time to respond to disruptions (Braunscheidel and Suresh, 2009; Christopher and Peck, 2004). An agile firm should first see all business processes clearly from beginning to end through collaborative planning with customers and suppliers (Christopher and Peck, 2004), identifying the locations and status of transiting entities captured in timely messages about events (Francis, 2008) and generating awareness on the current status of operating assets and the environment (Fiksel *et al.*, 2015; Petit *et al.*, 2013). Investing in IT capabilities enables transparency through integrated information-sharing and connectivity (Brandon-Jones *et al.*, 2014; Jüttner and Maklan, 2011; Melnyk *et al.*, 2010). Another approach to increase agility is to expedite adaptive activities in order to minimize losses and risks through streamlining processes, reducing in-bound lead times and removing nonvalue-added time (Christopher and Peck, 2004).

High-level *collaboration* is another way to significantly improve flexibility (Erol *et al.*, 2010). Collaboration is the ability to respond to supply chain disruptions with partners through collaborative planning (Christopher and Peck, 2004) and information sharing (Christopher and Peck, 2004; Jüttner and Maklan, 2011; Faisal *et al.*, 2006; Petit *et al.*, 2013) to coordinate the immediate response either with suppliers or customers (Scholten *et al.*, 2014).

9.4 Restorative activities

Restorative capacity reflects the ability to return a system to something near its original structure. Restorative activities most often involve repairs (Vugrin *et al.*, 2011). Firms often take restorative actions based on external resources, especially in the case of massive catastrophic events; systems may not be able to repair themselves, or they may not be able to do so rapidly enough to prevent unacceptably large consequences. Businesses may be able to perform repairs using their own local resources, but in most cases, these repairs could be better described as maintenance (Vugrin *et al.*, 2011).

10. Resilience measures

Resilience measures are a set of indicators designed to quantitatively measure the status of the resilience capacities. Consequently, resilience measures are applied to assess the resilience

performance of a firm before, during and after a disruption. Based on resilience measures, a firm would identify the capabilities or resources they should improve through resilience activities. Resilience measures are designed based upon the resilience capacities, so they are allocated to each of the four resilience capacities, as shown in Figure 10.

The *Predictive* performance of a resilient firm is measured by *awareness, vulnerability risks* and *preparedness*. *Awareness* involves an understanding of all possible vulnerabilities against all probable disruptions (Datta, 2017) through early-warning strategies (Saenz and Revilla, 2014) and continuity planning (Pettit *et al.*, 2010). *Vulnerability risks* reflect the possible weaknesses of a firm against a predicted disruption and the severity of the probable consequences (Sheffi and Rice, 2005). Vulnerability risks are calculated based upon the probabilities of disruptions and the severity of the disruptions' consequences (Sheffi and Rice, 2005). Severity refers to the number of firm components (e.g. human resources, products and processes) affected by the negative effects of different disruptions (Sanchis and Poler, 2013). Also, a firm should evaluate its *preparedness* to face disruptions by assessing if they have the knowledge, means and resources to be able to anticipate different disruptions (Sanchis and Poler, 2013).

The *absorptive* performance of a resilient firm is measured through responsiveness and robustness. *Responsiveness* is the ability to change quickly in terms of volume, mix or location as a function of changing conditions (Melnyk *et al.*, 2010). *Robustness* refers to the ability to resist against adverse changes (Wieland and Wallenburg, 2012). Robustness helps a firm retain its stability and function despite some disturbances (Wieland and Wallenburg, 2012; Meepetchdee and Shah, 2007; Durach *et al.*, 2015).

The *adaptive* performance of a resilient firm is measured through flexibility and agility. Flexibility is an antecedent for agility (Ponis and Koronis, 2012). Flexibility means creating options at various levels, developing ways and means of change across the range of options and providing freedom of choice to various actors (Sushil, 2001). Therefore, the flexibility of a resilient firm is measured by how many alternatives are proactively planned to adapt vulnerabilities to external conditions. Agility refers to how rapidly a firm responds to unpredictable changes (Braunscheidel and Suresh, 2009; Christopher and Peck, 2004). Two key ingredients of agility are visibility and velocity (Kamalahmadi and Parast, 2016). Visibility is the ability to see from the one end of the pipeline to the other. For example, visibility implies a clear view of upstream and downstream inventories, demand and supply

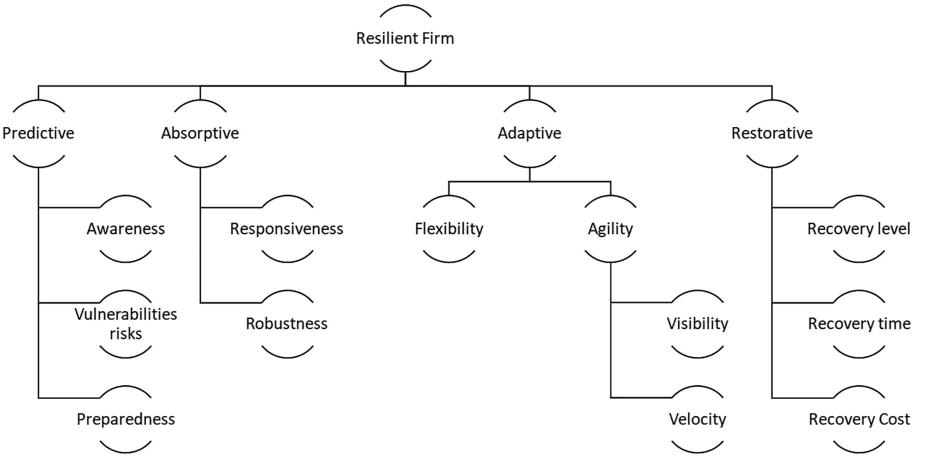

Figure 10.
Resilience performance measures

conditions, and production and purchasing schedules (Christopher and Peck, 2004). Visibility also generates awareness on the current status of operating assets and the environment (Fiksel, 2015) by using key performance indicator metrics to monitor performance (Ambulkar *et al.*, 2015; Melnyk, 2014). Velocity refers to how rapidly a firm reacts to changes (Christopher and Peck, 2004). Velocity in a risk event determines the loss that happens per unit of time (Barroso *et al.*, 2011; Jüttner and Maklan, 2011).

The *restorative* performance of a firm is measured by recovery level, recovery time and recovery cost (Sanchis and Poler, 2013). The recovery level refers to a firm's decision as to which level they should move after a disruption. Sometimes the level of recovery is not exactly the initial one. Recovery time denotes estimated time that is targeted by a firm in order to restore recovery stage. Similarly, recovery cost refers to estimated costs for restorative activities that are planned in disruption planning.

11. Developing an integrated resilience model

The development of an integrated functional model for resilience management used the PDCA framework (Dahlgaard *et al.*, 2008). The PDCA cycle is widely used in quality management and also applied as a reference model for business process design (Hammer, 2015). Basically, the logic of PDCA implies that a system continuously improves itself if the system 1) *Plans* to achieve its goals, 2) *Does* the planned activities, 3) *Checks* or assesses its performance and 4) *Acts* or implements feedback from the assessments to improve the plans. Similarly, the logic of PDCA is applied to develop resilience management, as shown in Figure 11. The resilience management cycle has four main elements: 1) resilience planning (representing *Plan)*, 2) Resilience activities (representing *Do)*, 3) resilience measurement (representing Check) and 4) innovation (representing Act).

The four main elements of the resilience management cycle are integrated into organizational *capabilities, resilience capabilities, resilience measures* and *disruptions*. The result is reflected in Figure 12. As shown in Figure 12, this study proposes that a resilient firm

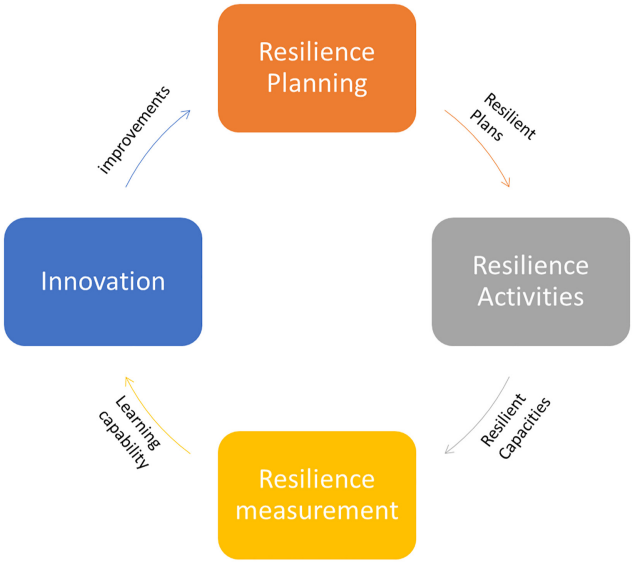

Figure 11.
Resilience management cycle

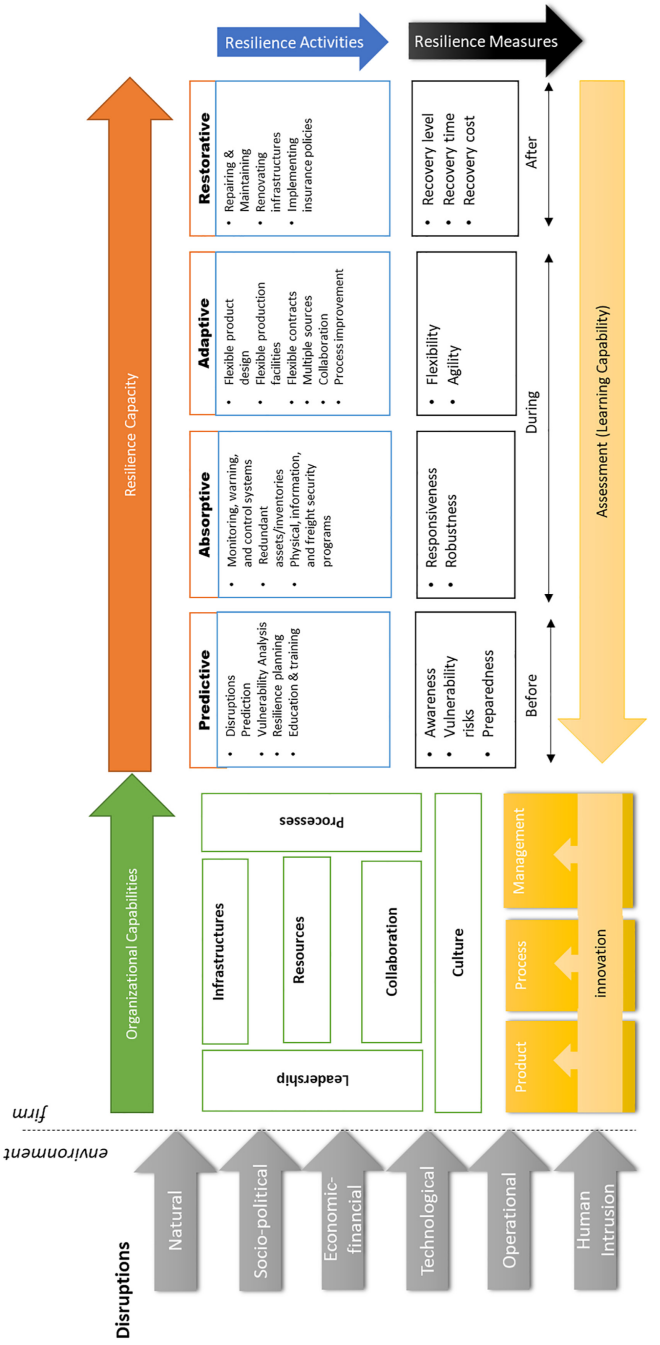

Figure 12.
Integrated model of organizational resilience

should have four main resilience capacities: predictive, absorptive, adaptive and restorative capacities that are aligned to the three stages of the disruption pattern shown in Figure 2.

Before a disruption, predictive capacity is achieved through predictive activities that include predicting high-risk disruptions, recognizing related vulnerabilities, planning required resilience activities and preparing human resources through education and training programs. Predictive capacity performance is measured by three measures introduced in Section 10: awareness, vulnerability risks and preparedness.

During a disruption, a resilient firm should have two resilience capacities: absorptive capacity and adaptive capacity. When a disruption hits a firm's capabilities, including infrastructures, resources and processes, the waves and shocks made directly by a disruption may take a few seconds, minutes, hours or days. During this time, a resilient firm should have been ready in advance to absorb the waves and shocks through absorptive activities: deploying monitoring, warning and control systems; preparing redundant assets and inventories; and implementing physical, information and freight security programs. Absorptive capacity performance is measured though two main measures: responsiveness and robustness (discussed in Section 10). After the direct impacts of a disruption, the disruption may have more consequences that affect the performance of the firm. For example, an earthquake may destroy buildings and infrastructures, but consequences such as fires and explosions may occur after it. To cope with the consequences of a disruption, a resilient firm should have adaptive capacity. Adaptive capacity is achieved through a set of adaptive activities that should have been foreseen in resilience plans. For example, considering flexibility in product design and production facilities, flexible contracts, having multiple sources, collaboration expansion with suppliers and process improvements are major examples of adaptive activities that facilitate adapting to the new conditions made by the consequences of a disruption and assist the resilient firm to return slowly to normal operating conditions. Adaptive capacity performance is measured mainly by flexibility and agility (discussed in Section 10).

After a disruption, when a resilient firm most likely faces long-term consequences, it needs to have restorative capacity to maintain and repair destruction, renovate infrastructures and make insurance claims to receive compensation for financial damages. Restorative capacity is normally expressed in terms of recovery level, recovery time and recovery cost, which are performance measures used to assess restorative capacity after a disruption.

Assessment of each of the resilience capacities using the performance measures delivers a learning capability that can improve the firm's resilience plans and consequently the firm's performance on the next disruption. According to lessons learned through the learning capability, innovation is implemented to improve product, process and management to increase resilience performance.

12. Theoretical contributions and practical implications

This study aimed to provide a more nuanced understating of the concept of organizational resilience. Through reviewing the articles in organizational resilience, this study provided more clarity to the dynamics of organizational resilience. This study also discussed the different phases of organizational resilience and the types of resources organizations need to develop to improve their resilience to disruption. This study makes several contributions to the theory and practice of organizational resilience that are outlined below.

12.1 Theoretical contributions

This study incorporates many important concepts of resilience at the firm level into an integrated model. A review of the literature found that the majority of concepts related to

resilience were fragmented, and they were introduced in isolation from each other with respect to organizational resilience. This study has assembled all of the concepts into an integrated model, and it has also mended some inconsistencies in the concepts, introduced in Section 3, by redefining the concept of resilience. The concept of resilience and the process model of resilience management, shown in Figure 11, are two pillars used to develop the integrated model of resilience shown in Figure 12. In achieving the integrated model of resilience, this study makes four theoretical contributions.

In this study's first contribution, the integrated model of resilience specifically designates and provides a specific idea to *time* as the main factor used to differentiate between the resilience capacities required for different stages of a disruption. Sheffi and Rice, (2005) introduced how the performance of a firm is affected *before*, *during* and *after* a disruption, but they pointed only to responsiveness and flexibility as the main resilience capacities required. This study identified four resilience capacities for the stages before, during and after a disruption and determined what features each resilience capacity should have, according to the related stage.

This study's second contribution is to provide more accurate terminologies for organizational resilience by reconciling the issues recognized in the literature review. As discussed in Section 3, the current literature reviewed in this study suffers from the issues shown in Table 1, such as inaccurate meaning for main concepts such as "adapt" (Ali *et al.*, 2017; Linkov *et al.*, 2013; Pech and Oakley, 2005; Ponomarov and Holcomb, 2009), contradictory meanings of resilience measures and resilience activities (Ali *et al.*, 2017), poor definition for some key concepts such as capacity (Pettit *et al.*, 2010; Proag, 2014) and lack of discrimination between key concepts (Ali *et al.*, 2017). To resolve the issues, we approached the redefinition of resilience by discriminating between *capability* and *capacity*. Subsequently, we developed the concept of resilience based on the four main components called resilience capacities: predictive capacity, absorptive capacity, adaptive capacity and restorative capacity.

This study's third contribution is discriminating between *capacity* and *capability* based on their definition in thesauruses such as the Oxford English Dictionary. Subsequently, we introduced resilience capacities versus organizational capabilities, which is widely discussed in the literature of the resource-based view (Prahalad and Hamel, 2003; Wernerfelt, 1984). Section 7 discussed the impact on resilience of organizational capabilities, such as leadership, culture, business processes, infrastructures, collaboration and resources. *Leadership* changes behaviors (Harland *et al.*, 2005; Nguyen *et al.*, 2016) and facilitates cognitive, emotional and behavioral adaptation (Harland *et al.*, 2005). *Culture* has a positive impact on flexibility and adaptability (Mandal, 2017; McManus *et al.*, 2008; Sheffi, 2005). *Business processes* have a potentially positive impact on predictive, absorptive, adaptive and restorative capacities (Sincorá *et al.*, 2018). *Infrastructures* are essential to withstand against disruptions and rapidly recover from disruptions (Francis and Bekera, 2014). *Collaboration* is known as a resilience strategy (Carvalho *et al.*, 2012a, b) that mitigates disruption damage (Kache and Seuring, 2014) and improves performance (Kache and Seuring, 2014). Finally, *resources* allow firms to absorb the initial shocks of disruptions and to more quickly recover from the long-terms impacts of disruptions (Rice and Shaeffi, 2005). While organizational capabilities related to resilience have been discussed in the previous literature, these capabilities have been discussed in isolation from each other, providing limited insight into organizational resilience. By introducing the resilience capacities, this study made it possible to achieve a comprehensive definition of resilience and to specify all the resilience activities required to achieve each of the resilience capacities.

This study's fourth contribution relates firm innovation to firm resilience and discusses how a firm's innovativeness capability can enhance the firm's resilience capacities to respond to disruptions. Prior studies have addressed the relationship between firm innovation and

firm resilience (Kamalahmadi and Parast, 2016; Parast *et al.*, 2019); however, those studies did not describe the process by which firm innovation actually enhances firm resilience. This study provides a more process-oriented approach to create the linkage between firm innovation and firm resilience by identifying innovativeness as one of the components of the resilience management cycle, shown in Figure 11, which is implemented in the integrated model shown in Figure 12.

12.2 Managerial implications

This study's first managerial contribution pertains to providing a practical guide for operations and supply chain managers to view resilience as a dynamic process that involves a component of time. With knowledge of resilience capacities, resilience activities and resilience measures, operations and supply chain managers can develop their own roadmaps to achieve resilient firms. In addition, they can design a set of resilience performance measures and embed them into their existing performance measurement system to navigate how the firm is progressing towards becoming a more resilient firm. Also, they can implement their learning from performance assessments to update the resilience activities in their roadmap towards becoming a more resilient firm.

This study's second management implication is to provide a comprehensive measurement model to assess resiliency at firm level. This study developed a structure of measures aligned with the four resilience capacities required before, during and after disruptions. The resilience measures provide input for a learning capability to use the lessons learned from disruptions and resilience activities to improve products, processes and management. Managers can embed the offered measurement model in their existing performance management systems. Thus, their organizations will be able to track their performance against disruptions.

This study's third managerial contribution is that resilience management is a dynamic process that needs to be developed with the understanding of the different types of resilience capacities. An integrated functional model was designed and shown in Figure 12. The model can be adapted to current businesses processes to ensure that an organization is resilient from a process perspective.

12.3 Future studies

Resilience activities vary depending on the nature of disruptions. Some studies introduce resilience activities specifically designed for a particular resilience. For example, Linkov *et al.* (2013) discussed resilience activities for cyber attacks and Hohenstein *et al.* (2015) reviewed some resilience activities against supply chain disruptions. Still, we can learn deductively from resilience activities experienced in different areas and expand our theoretical knowledge in resilience management to achieve a reference model of resilience activities. To do so, researchers can extract resilience activities experienced in different areas published in the literature, building a database of the activities and determining their applications.

Human intrusions are a topic that has been relatively overlooked in the literature on resilience, despite a growing number of subversive activities, such as cyber attacks (Loukas, 2015). The majority of the studies published about human intrusions are related to cyber attacks (Linkov *et al.*, 2013), which is more technical rather than managerial. There is a significant gap from the management point of view in the study of human intrusions. Studying about the types of human intrusions, their consequences and how companies can cope with this type of disruption can enrich the literature of resilience.

Future studies can examine the relative importance of resilience capacities that are a strategic factor in resilience planning before the occurrence of disruptions. Decision makers should determine in resilience planning what degree of resilience should be achieved before, during and after disruptions. To do so, resilience measures are a suitable means to evaluate

and set targets in resilience planning. There are a few studies that examine the relative importance of a select set of organizational capabilities that enhance firm resilience (i.e. resilience enhancers). For example, Soni *et al.* (2014) developed a resilience index to evaluate the relative effect of resilience. Carvalho *et al.* (2012a, b) developed a simulation model and evaluated the impact of different resilience strategies before and after disturbances. Future studies need to provide a more comprehensive assessment of the impact of different capacities, capabilities and resources on improving organizational resilience.

One important aspect of organizational resilience is to identify the major sources of disruptions in an organization and to develop resilience activities that can improve firm resilience to disruptions. Because organizations have limited resources, they need to make investment decisions about the types of resilience capacities they need to have to be more responsive to disruptions. Parast and Shekarian (2019) examined the effect of different types of disruptions on organizational performance. They identified organizational capabilities that improve an organization's response to disruptions.

13. Conclusion

Despite the publication of many papers in resilience at the firm level and the supply chain level, there are still issues in terminology and consequently in resilience discourse among researchers. In this paper, resilience is redefined by applying the knowledge extracted from the literature and the original semantic meaning of key terms. The definition of resilience is constructed based on four main resilience capacities: predictive capacity, absorptive capacity, adaptive capacity and restorative capacity. Subsequently, resilience activities required to achieve the resilience capacities are extracted from the literature and introduced. Also, resilience performance measures are assembled in a hierarchical model aligned with the four resilience capacities. Finally, resilience capacities, resilience activities and resilience measures are integrated in a functional model. The integrated model also reflects the way resilience performance measures provide learning capability to feed innovation in order to improve the capabilities required for a resilient firm. In general, the integrated model is an extension of the resilience management cycle, considering all main concepts defined and developed in this paper.

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Appendix

Table A1. Resilience definitions

Number	Definition	Level of analysis	Activities	Ability	Respond	Changes
1	"The ability of a system to withstand the stresses of environmental loading based on the combination/ composition of the subsystems, their structural inter-linkages and the way environmental change is transmitted and spread throughout the entire system" (Horne, 1997)	System	Combination/composition of the subsystems, their structural interlinkages	Ability	Withstand	The stresses of environmental loading; environmental change
2	"A fundamental quality of individuals, groups, organizations, and systems as a whole to respond proactively to significant change that disrupts the expected pattern of events without engaging in an extended period of regressive behavior" (Home and Orr, 1997)	Individuals, groups Organizations And systems	N/A	quality	Respond proactively	Significant changes
3	"Resilience is the ability of an individual or organization to expeditiously design and implement positive adaptive behaviors matched to the immediate situation, while enduring minimal stress" (Mallak, 1998)	An individual or organization	design and implement positive adaptive behaviors	Ability	Enduring minimal stress	Immediate situation
4	"The ability and capacity to withstand systemic discontinuities and adapt to new risk environments" (Starr *et al.*, 2003)	Organization	N/A	Ability and capacity	Withstand Adapt	Systemic discontinuities new risk environments
5	"The capacity of a system to tolerate disturbances while retaining its structure and function" (Fiksel, 2003)	System	Retaining its structure and function	Capacity	Tolerate	Disturbances

(*continued*)

Table A1.

Number	Definition	Level of analysis	Activities	Ability	Respond	Changes
6	"Resilience refers to the capacity for continuous reconstruction. It requires innovation with respect to those organizational values, processes and behaviors that systemically favor perpetuation over innovation" (Hamel and Välikangas, 2003)	N/A	Innovation with respect to organizational values, processes and behaviors	Capacity	Continuous reconstruction; systemically perpetuation	N/A
7	"The capability to self-renew over time through innovation" (Reinmoeller and Van Baardwijk, 2005)	N/A	Innovation	Capability	Self-renew over time	N/A
8	"The ability to bounce back from a disruption. Resilience, in turn, can be achieved by either creating redundancy or increasing flexibility." (Sheffi and Rice, 2005)	firm	Creating redundancy or increasing flexibility	Ability	Redundancy and flexibility	Disruptions
9	"Resilience conveys the properties of being able to adapt to the requirements of the environment and being able to manage the environment's variability" (McDonald, 2017)	N/A	N/A	Properties of being able	Adapts to the requirements of the environment; manage the environment's variability	Environment variabilities
10	"The capacity to anticipate unsafe and unexpected events for organizational survival in the face of threats, including the prevention or mitigation of failures in the systems" (Woods and Cook, 2017)	Organization; systems	Anticipate; prevention; mitigation of a failure	Capacity	Redundancy and flexibility	Unsafe and unexpected events

(*continued*)

Table A1.

Number	Definition	Level of analysis	Activities	Ability	Respond	Changes
11	"A resilient system encompassed the actions, including avoiding, adsorbing, adapting to and recovering from disruptions" (Madni and Jackson, 2009)	System	N/A	Actions	Avoiding, adsorbing, adapting to and recovering from	disruptions
12	"The emergent property of organizational systems that relates to the inherent and adaptive qualities and capabilities that enable an organization's adaptive capacity during turbulent periods. The mechanisms of organizational resilience thereby strive to improve an organization's situational awareness, reduce organizational vulnerabilities to systemic risk environments and restore efficacy following the events of a disruption" (Burnard and Bhamra, 2011)	Organization, organizational systems; mechanism	Improve situational awareness, reduce organizational vulnerabilities	Emergent property that relates to inherent and adaptive qualities and capabilities	Restore efficacy; adapt	Turbulent periods, the events of a disruption
13	"A 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 organizational survival" (Lengnick-Hall *et al.*, 2011)	firm	Develop situation- specific responses to and ultimately engage in transformative activities	Ability	Effectively absorb	Disruptive surprises that potentially threaten organizational survival

(*continued*)

Table A1.

Number	Definition	Level of analysis	Activities	Ability	Respond	Changes
14	"Resilience provides an entity with the ability to repair, replace, patch or otherwise reconstitute lost capability or performance (and hence effectiveness), at least in part and over time, from misfortune, damage or a destabilizing perturbation in the environment" (Alberts, 2011, p. 218)	Entity	To repair, replace, patch	Ability	Reconstitute lost capability or performance	Misfortune, damage or a destabilizing perturbation in the environment
15	The capacity of an organization of construction projects to absorb pressure, develop positive adaptive behaviors and quickly recover from adverse impacts in order to preserve functions to achieve expected targets despite being subjected to disruptive events in a complex and dynamic environment (He *et al.*, 2018)	Organization	To preserve functions to achieve expected targets	Capacity	Absorb pressure, develop positive adaptive behaviors, and quickly recover from adverse impacts	Disruptive events in a complex and dynamic environment
	The measurable combination of characteristics, abilities, capacities or capabilities that allows an organization to withstand known and unknown disturbances and still survive (Ruiz-Martin *et al.*, 2018)	Organization	N/A	Characteristics, abilities, capacities or capabilities	Withstand, survive	Known and unknown disturbances