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# Developing a conceptual framework for investigating the resilience of construction SMEs and their supply chains against extreme weather events

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# **Developing a conceptual framework for investigating the resilience of construction SMEs and their supply chains against extreme weather events**

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## **Abstract**

Projections into future increasingly suggest that the intensity and frequency of Extreme Weather Events (EWEs) will increase in the future. This has demanded the business organisations as well to be prepared to face the increasing risk of EWEs, in order to ensure their business continuity. However, current evidence base suggests that businesses, especially SMEs, are not adequately prepared to face the threat of such events. Ability to adequately prepare them has been hindered by the lack of in depth studies addressing this issue. The paper presents a doctoral study designed to investigate the resilience of SMEs operating in the construction sector; which is said to be a highly vulnerable sector for the impacts of EWEs, and their supply chains to EWEs. A conceptual framework developed to investigate this issue is presented and explained. It is argued that the resilience of construction SMEs and their supply chains against EWEs can be improved by a combination of reducing their vulnerability, enhancing coping capacity and implementing coping mechanisms. Importance of undertaking a broader view to include the whole supply chain in making business decisions with regard to EWEs by SMEs is also highlighted.

**Keywords:** Business continuity, Construction, Resilience, SMEs, Supply chain

## **1 Introduction**

Evidence shows that there has been a long-term upward trend in the number of EWEs since the latter part of the 20th century (Munich Re Group, 2008), which has experienced over 170 “billion-dollar events” related to weather extremes, in particular windstorms, floods, droughts and heatwaves (Beniston and Stephenson, 2004). It is projected that such weather extremes will further increase in number and severity in future, especially due to climate change impacts (Stern, 2007). Consequently, costs of EWEs are also expected to further escalate in the future, and as the Stern Review (2007) reveals, the average annual costs of extreme weather could reach about 0.5 - 1% of world’s GDP by the middle of the 21st century. Resilience of businesses, their ability to sustain key business operations during a disruption such as extreme weather despite adverse impacts upon their activities, is fundamental to societal resilience (Paton and Hill, 2006). The role of construction industry is even more important, as they have to play a significant role during the recovery phases following a disruption.

Mills (2003) argues that the construction sector is “perhaps the most vulnerable” to weather extremes, “with exposures ranging from damage to physical infrastructure to disruption of business operations, to adverse health and safety consequences for building occupants”. Extreme weather can create a variety of effects on construction sector SMEs including direct effects such as disruption to site works and indirect effects due to disruptions to deliveries and utility supplies (Metcalf et al., 2009). Centre for Economics and Business Research Ltd (CEBR) has said that there will be around 2000-3000 additional business failures in the UK as a result of the disruptions caused by the heavy snowfall in 2009, and that many of these businesses would be from the construction and retail sectors (McWilliams, 2009). As the UK construction sector is largely dominated by the Small and Medium-scale Enterprises - SMEs (BERR, 2008), which are said to be highly vulnerable to EWE related hazards (Crichton, 2006), EWEs are of specific importance to the UK construction industry. Further, Harty et al (2007) through a review of construction future studies identify EWEs as a specific issue that would be of importance to the construction industry in future.

This paper aims to present a conceptual framework developed as part of a PhD research study aimed at developing and validating a decision making framework for improving the resilience of construction sector SMEs and their supply chains against EWEs. The research study is part of a multidisciplinary research project titled “Community Resilience to Extreme Weather – CREW”. The paper discusses the importance of improving the resilience of construction SMEs against EWEs and briefly identifies the concepts of resilience and related terms. It then discusses the conceptual framework developed for the

research and concludes by stressing the need for further research in this area and setting out the way forward of the research.

## **2 EWEs and construction sector SMEs**

### **2.1 *Extreme weather events***

Extreme weather events are defined as “meteorological conditions that are rare for a particular place and/or time” for the purpose of the Community Resilience to Extreme Weather - CREW research project in which this PhD research is a part of. While the general perception of EWE tends to bring images such as floods and storm surges that have the potential to create large scale disasters, within this research, a much broader view is taken in conceptualising a weather extreme to mean meteorological conditions that are rare for a particular place and/or time. This definition is similar to the definitions put forward by Francis and Hengeveld (1998), and Intergovernmental Panel on Climate Change - IPCC (2007). In addition, it recognises that rarity can change over time. Although the word “rare” is used here, the term EWEs is also used in general to denote weather of sufficient severity to generate a hazard. Examples for weather extremes include heavy rainfall, heavy snowfall, extreme temperatures (both high and low), storms as well as flooding and heat waves. Although situations like flooding and heat waves are included under the term “extreme weather events” here, they indeed are “extreme weather hazards” rather than “extreme weather events”. For instance, flooding is a hazard rather than a weather condition itself. It may occur due to a weather extreme (e.g. heavy rainfall) coupled with some other causes as well. However, the difference between a hazard and a weather condition is often neglected and the term “extreme weather events” is used to cover the weather related hazards as well. The IPCC definition too goes on to say that EWEs “may typically include floods and droughts” (IPCC, 2007). In this paper also the term EWEs is used to include extreme weather hazards as well.

### **2.2 *Construction SMEs and EWEs***

According to SME statistics released by the Enterprise Directorate Analytical Unit of Department for Business, Enterprise and Regulatory Reform - BERR, over 99.9% of private sector enterprises operating in the UK construction industry employ less than 250 people and thus fall into the category of SMEs (BERR, 2008). SMEs collectively generate over two thirds of the employment (83.8%) and turnover (67.4%) in the construction sector (BERR, 2008). Along with the sectors like agriculture, education, and health and social works, construction is a sector in which the contribution of SMEs is significantly high in terms of employment and generation of turnover. Construction, based on the above figures, can be identified as an industry which is largely dominated by the SMEs as opposed to the sectors like mining

and quarrying, financial intermediation, transport, and manufacturing in which the large organisations contribute to the higher share of employment and generation of turnover. Thus, SMEs are highly important to the successful operation of the UK construction sector and the cumulative effect of their failure can have a significant impact on the whole industry.

SMEs, in general, are considered as highly vulnerable to various disruptions; primarily because of the limited resources available to them (Bannock, 2005) as they, by definition, are limited by human and financial resource constraints. For example, The European Union definition of an SME is “an enterprise which employ fewer than 250 persons and which has an annual turnover not exceeding €50 million, and/or an annual balance-sheet total not exceeding €43 million” (European Commission, 2006).

Crichton (2006) identifies SMEs as the section most vulnerable to the impact of extreme weather of the UK economy. Although weather extremes affect both large firms and SMEs equally, they may affect SMEs disproportionately hard (Tierney and Dahlhamer, 1996; Finch, 2004) The fact that SME owners are often hit twice by EWEs; as local citizens and as business owners (Runyan, 2006) due to a majority of SMEs being local in their operations and rooted in local communities (Bannock, 2005) also makes them more vulnerable. For instance, a local branch of a large business organisation being out of business for few days due to a EWE might not create a substantial effect on the wider organisation. However, a disruption of a similar magnitude might lead to a complete failure in the case of a local SME.

Previous research reveals that small businesses are not adequately prepared to cope with and recover from the risk of EWEs and other natural hazards (Tierney and Dahlhamer, 1996; Alesch et al., 2001; Yoshida and Deyle, 2005; Crichton, 2006; Dlugolecki, 2008). For instance, 90% of small businesses do not have adequate building insurance cover (AXA Insurance UK, 2008) and only about 30% have a business continuity plan (Woodman, 2008). A study commissioned by the Business Link South East (Norrington and Underwood, 2008) has found that only 20% of construction sector SMEs (from a survey sample of 244 construction sector SMEs located in South East of England) had a plan to deal with business interruption. According to their study, construction sector SMEs were the least prepared in terms of business continuity compared with the other industry sectors studied; namely manufacturing, retail, business/financial services, transport, and land based SMEs. Although the dearth of research specific to construction sector SMEs and EWEs limits the ability to comment on their vulnerability to EWEs, it can be identified that SMEs in general are highly vulnerable to EWEs when compared with their larger counterparts.

### ***2.3 Effects of EWEs on construction SMEs***

A recent study commissioned by Climate South East (Norrington and Underwood, 2008) has identified that damage to property/stock and reduction in customer visits as the major impacts experienced by SMEs located in South East of England during the two years prior to the study. Damage to property/stocks has been identified as the main effect of rain/flooding and winds whereas reduction in customer visits is identified as the main effect from high/low temperatures. Reduced trade in weather dependent goods/services and negative impacts on staff travel and working conditions are the other commonly experienced impacts according to the study conducted by Norrington and Underwood (2008).

Another study conducted on behalf of Chartered Management Institute (Woodman, 2008) has identified that staff unavailability for work (53%), premises flooded (38%), and suppliers disrupted (27%) as the main negative effects experienced by UK businesses subjected to their study in 2007. Nearly 50% of the respondents in their study are SMEs whereas the remaining are large businesses. Interestingly, the fourth highest ranked effect experienced by the businesses was increase in trade/demand for services. In the study by Norrington and Underwood (2008), some of the businesses also experienced positive impacts due to extreme weather events. This shows that although the effects of EWEs tend to be negative in many obvious ways, there can also be beneficial impacts and consequences as well (Meehl et al., 2000). For an instance, an industry like construction may benefit from increased demand for flood-proofing techniques in flood-zones (UKCIP, 2003) and from the increased need for reconstruction and more robust structures (Dlugolecki, 2004).

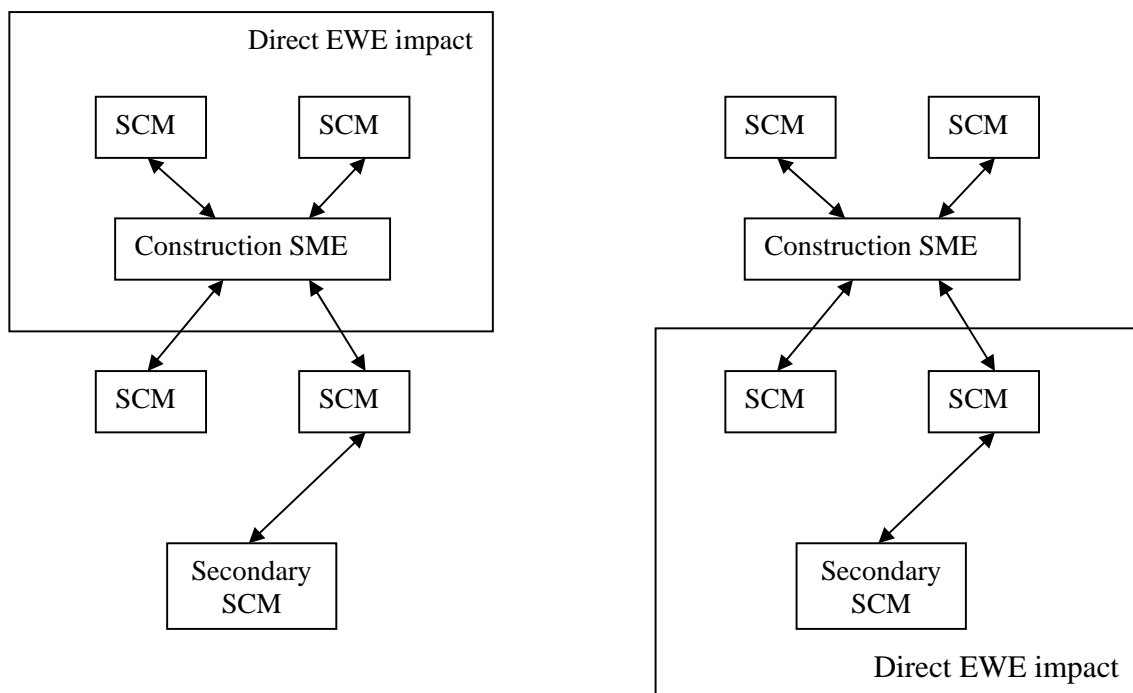
Another study conducted by Heliview Research on behalf of Atradius Insurance (2008) covering six European countries including the UK, has identified that increase in total cost (51%), decrease in turnover (43%), damage to buildings and other tangible assets (20%) as the main negative effects experienced by businesses in 2007. Productivity losses, extraordinary costs and less profit are the other main negative effects experienced by those businesses (19%). More than 60% of businesses subjected to this study were SMEs.

Although the above studies provide significant information about the effects created by EWEs on SMEs in general, none of those studies provide information pertaining to different industry sectors; more importantly, specific to the construction industry. As these effects are likely to vary according to the industry sector, the dearth of research specific to different industry sectors consequently has curtailed the ability to introduce coping mechanisms for SMEs specific to their industry sector. For instance, through a review of literature of studies on disaster response of businesses, Webb et al (2002) identify economic

sector as one of the characteristics affecting the survival and long term recovery of businesses affected by disasters. Addressing this gap of knowledge, this research is designed to develop a decision making framework for improving the capacity for resilience of construction SMEs and their supply chains.

As discussed by the authors in a previous publication (Wedawatta et al., 2010), study of supply chain relationships with regard to extreme weather response is important as supply chain disruptions can create a substantial impact even without a particular SME being directly affected by an EWE and vice versa. Figure 1 shows the relationships that a construction SME can have with its supply chain members in relation to EWE vulnerability, impacts and survival. The vital issue to recognise here is that a construction SME does not need to be physically located in a EWE impacted locality to have an impact on its business operations.

**Figure 1 - Relationship of Construction SMEs and supply chain members (SCM) in relation to EWEs - Adapted from Zhang et al (2009)**



### 3 Resilience to EWEs

International Strategy for Disaster Reduction - ISDR (2009) identifies resilience as “the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions”. According to Intergovernmental Panel on Climate Change

(2007), resilience is “the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change”. Whilst the latter definition highlights a systems’ ability of absorbing disruptions, the former definition also acknowledges that disruptions can occur and thus highlights the ability to recover from a disruption as well. McManus et al (2007) identify resilience, in an organisational context, as a function of an organisation’s situation awareness, management of keystone vulnerabilities, and adaptive capacity in a complex, dynamic and interconnected environment. For the purpose of this research, a working terminology developed for the CREW research project; in which this research a part of, will be used. Accordingly, resilience is defined as “the ability to prevent, withstand, recover from and learn from the impacts of extreme weather hazards”. This definition goes beyond the ISDR and IPCC definitions, and recognises the importance of learning from EWEs once experienced so that the lessons learnt can be used to prepare better for future occurrences.

Various researchers have attempted to represent resilience from different perspectives. For instance, Cutter et al (2008) have looked at community resilience from a natural hazards perspective. Cutter et al in their model has recognised that, whilst there is a growing body of research focussing on defining the dimensions of community resilience, little attention has been paid to the development of consistent factors or standard metrics to quantify community resilience (Jones and Few, 2009). They have addressed this shortcoming by identifying a set of variables to measure community resilience. According to the Disaster Resilience of Place (DROP) model developed by Cutter et al (2008), “the total hazard or disaster impact is a cumulative effect (or sum) of the antecedent conditions, event characteristics, and coping responses”. The overall impact will be moderated by the absorptive capacity of the community being affected. Cutter et al (2008) identify absorptive capacity as “the ability of the community to absorb event impacts using predetermined coping responses”. McManus et al (2007), in their framework developed to assess and analyse organisational resilience, have identified 15 key resilience indicators which represent key resilience issues in an organisation. These indicators are grouped under three main interrelated categories; situation awareness, management of keystone vulnerabilities, and adaptive capacity. Some of the key frameworks on resilience, from a hazard perspective, are given in Table 1.

Table 1 - Frameworks on Resilience from a hazard perspective

<i>Source</i>	<i>Context</i>	<i>Focusing on</i>	<i>Components of resilience</i>
<i>Bruneau et al. (2003)</i> <i>Tierney and Bruneau (2007)</i>	<i>Seismic, Disasters</i>	<i>Communities, Infrastructure systems</i>	<i>Robustness</i> <i>Redundancy</i> <i>Resourcefulness</i> <i>Rapidity</i>
<i>Paton (2007)</i>	<i>Natural hazards</i>	<i>Societal resilience</i>	<i>Personal - Critical awareness, Self efficacy, Sense of community, Outcome expectancy, Coping, Resources</i> <i>Community – Collective efficacy, Participation, Commitment, Information exchange, social support, Decision making, Resources</i> <i>Institutional – Empowerment, Trust, Resources, Mechanisms for assisting community, Problem solving</i>
<i>McManus et al. (2007)</i>	<i>Disasters</i>	<i>Organisational resilience</i>	<i>Situation awareness – Roles and responsibilities, Understanding of hazards and consequences, Connectivity awareness, Insurance awareness, Recovery priorities</i> <i>Management of keystone vulnerabilities – Planning strategies, Participation in exercises, Capability and capacity of internal and external resources, Organisational connectivity</i> <i>Adaptive capacity – Silo mentality, Communications and relationships, Strategic vision and outcome expectancy, Information and knowledge, Leadership, management and government structure</i>
<i>Cutter et al (2008)</i>	<i>Natural disasters</i>	<i>Community resilience</i>	<i>Antecedent conditions</i> <i>Disaster severity</i> <i>Time between hazard events</i> <i>Influences from exogenous factors</i>

## 4 Developing a conceptual framework to investigate the resilience of construction SMEs

### 4.1 Conceptual frameworks in PhD research

Miles and Huberman (1994) mention that “a conceptual framework explains, either graphically or in narrative form, the main things to be studied – the key factors, constructs or variables – and the presumed relationships among them”. According to them a conceptual framework can either be rudimentary or elaborative, theory-driven or commonsensical, descriptive or even casual. Yin (2003) mention that the researchers are able to illustrate the main concepts pertaining to the study, as well as to illustrate how the concepts are interrelated and the circumstances within which the concepts and interrelationships



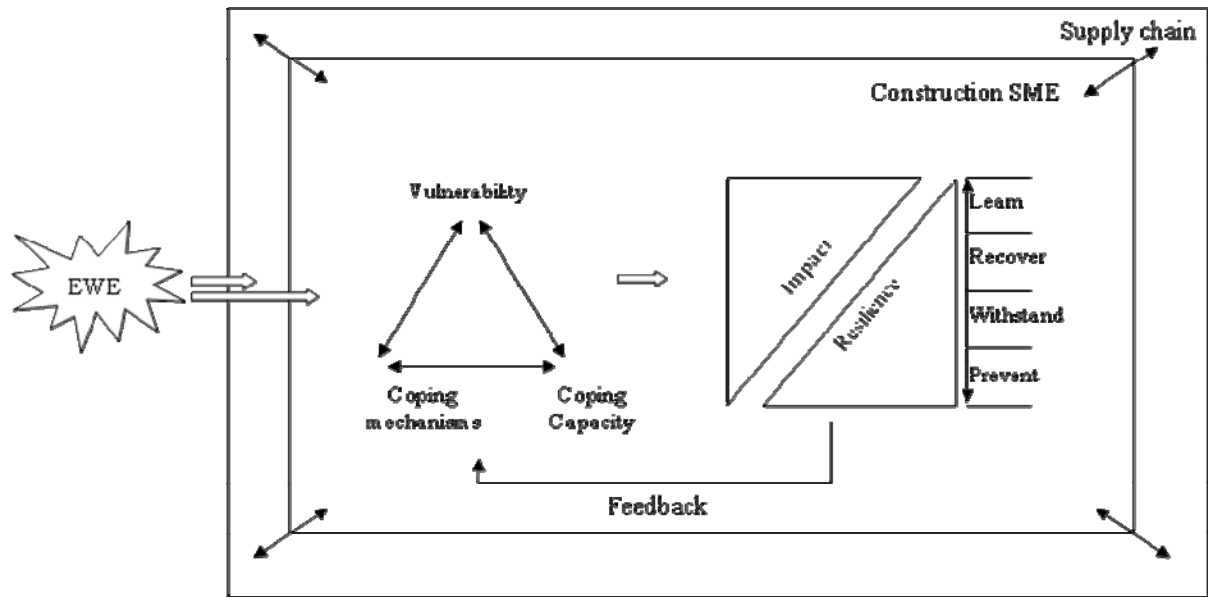
are said to be true by conceptualising the phenomenon under study. Summarising several views on conceptual frameworks, Kulatunga (2008) identifies main concepts, their interrelationships and the presence of a boundary within which the concepts and their interrelationships are applicable as the constituent parts of a conceptual framework.

According to Miles and Huberman (1994), developing a conceptual framework is an iterative process. A conceptual framework once developed will be revisited and amended as required during the course of a study, as the study progresses. However, having a conceptual framework in a research study is important, as it provides a sense of direction and focus for the study. Focusing and bounding functions of conceptual frameworks is highlighted by Miles and Huberman (1994). Further, Easterby-Smith et al (2008) mention that the conceptual models are meant to guide and align the thinking of researchers into more productive channels but not to restrict their thinking. It is further identified that different researchers might come up with different conceptual representations for the same general topic, depending on their educational, cultural backgrounds and research experience. Therefore, it is important to have a framework which represents how the individual researcher conceptualise his/her research, in order for the study to be further developed productively.

#### ***4.2 Conceptual framework of the research***

Figure 2 shows the conceptual framework developed for this research. As mentioned in the introduction, the aim of this research is to develop and validate a decision making framework for improving the resilience of construction sector SMEs and their supply chain against EWEs. The conceptual framework depicts the expected achievements by the use of the decision making framework developed by this research. This framework is developed as an integral part of a PhD research which is currently in progress and therefore is neither conclusive nor empirical.

The conceptual framework incorporates the view of Cutter et al (2008), in which the impact of an EWE on a certain entity is identified as a cumulative effect of several key issues in addition to the characteristics of the EWE itself. The level of impact and thereby the resilience will depend on a number of complex and interrelated issues.



**Figure 2 - Conceptual framework of the research**

In this PhD research, the impact of a EWE and thereby its resilience is viewed as a cumulative effect of the vulnerability, coping mechanisms and coping capacity of a certain SME. It is thought that the presence or absence of coping mechanisms and coping capacity coupled with the vulnerability of a certain SME will determine what level of resilience it can achieve against EWE impacts. These three issues are not mutually exclusive, but overlapping and interrelated. This research seeks to investigate how the EWE resilience of construction SMEs and their supply chain can be enhanced by a cumulative of managing vulnerability, implementing coping mechanisms, and improving coping capacity. Thus, the decision making framework to be developed will be focused around these three key issues.

Although the concept of vulnerability has been used in different research traditions, a proper agreement over its meaning is still to be arrived at (Gallopín, 2006). Inter Governmental Panel on Climate Change (IPCC) define vulnerability as “the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes” (IPCC, 2007). It further identify vulnerability as “a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity”. International Strategy for disaster Reduction (UNISDR, 2009) defines vulnerability as “the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard”. These two definitions deal with climate change and natural disasters respectively, but not specifically on EWE context. As this research is related to a multidisciplinary research project titled “Community Resilience to Extreme Weather –

CREW”, working definitions developed for the aforementioned research study are adapted for the purpose of this research. Accordingly, vulnerability is defined as “the characteristics and circumstances of humans and human systems that determine how susceptible they are to the impact of EW hazards”. In a SME context, in broad terms, it relates to the extent to which a particular SME can be harmed by a hazard.

UNISDR (2009) defines coping capacity as “the ability of people, organizations and systems, using available skills and resources, to face and manage adverse conditions, emergencies or disasters”. This involves resource management to cope up with hazards before, during and after the occurrence of a hazard. Coping capacity, in this research, is defined as “the ability of people or organisations to limit adverse consequences of EW hazards, using available resources and capabilities”. This definition is quite synonymous with the definition of resilience applicable to this research; however depicts a rather reactive approach whereas the resilience definition also embraces a proactive approach. This definition, like that of ISDR, also highlights the importance of management of resources and abilities, in this case available to SMEs. Coping mechanisms are defined as “actions that increase the ability to prevent, tolerate and/or recover from impacts” in this research. These may include both physical and non-physical actions such as obtaining business interruption insurance, business continuity planning, flood defences etc.

A somewhat similar framework for assessing and improving organisational resilience has been proposed by McManus et al (2007), in which the resilience is identified as “a function of an organisation’s situation awareness, management of keystone vulnerabilities, and adaptive capacity in a complex, dynamic and interconnected environment”. Their framework for organisational resilience focuses on organisations in general and their resilience to disasters in general. However, since this research is primarily focusing on SMEs and their resilience to EWEs, a somewhat different framework is proposed, especially considering the characteristics of SMEs in comparison to larger businesses as well as the aim and objectives of the research. As mentioned above, the framework addresses the aim and the objectives of the PhD research. This framework will be revisited and further developed as the study progresses and as the evidence emerges.

## **5 Conclusion**

This paper presented a conceptual framework developed to represent the focus of a PhD study, aimed at developing a framework for improving the resilience of construction SMEs and their supply chains against EWEs. The conceptual framework developed identifies the importance of reducing vulnerability,

improving coping capacity as well as implementing coping mechanisms / strategies as fundamental for improving resilience in an organisational context. These three interrelated concepts are expected to be used in order to limit the adverse impacts of EWEs on construction SMEs and their supply chains and thereby to improve their capacity for resilience. Next stages of this research will involve the study of research methodological perspectives and developing a robust research methodology for the research.

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